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Improving Tactical Intelligence Analysis: A Demonstration

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by

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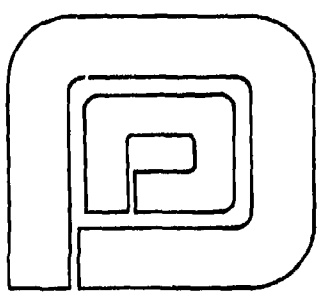

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This report describes a research study conducted by Decisions and Designs, Inc. (DDI), in conjuction with the Army Research Institute (ARI) and the Army Intelligence Center and School (USAICS). The purpose of the study was to test whether tactical intelligence analysis could be improved by using an interactive Bayesian inference aid. The study was performed with experienced tactical intelligence analysts (officers and enlisted personnel) and inexperienced but trained analysts (officers who had completed their training at USAICS). Two hypotheses guided the study. The first hypothesis was that experienced

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and inexperienced analysts working with the aid would be better able to discriminate between the most and least likely opposing force (OPFOR) courses of action than analysts working without the aid. The second hypothesis was that this improved performance would be the result of significantly less conservatism with than without the interactive Bayesian aid. Both hypotheses were confirmed. Discussions with experienced tactical intelligence analysts indicated that such a finding could have significant implications for improving tactical intelligence collection and analysis.

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EXECUTIVE SUMMARY

The subjective revision process inherent in tactical intelligence analysis can be conceptualized as a Bayesian inference problem. Experimental research in which participants' inferences have been compared with those prescribed by Bayes' Theorem, for tasks other than tactical intelligence analysis, has shown that people have considerable difficulty making judgments consistent with Bayes' Theorem. Furthermore, the research suggests that this difficulty can be overcome by using interactive computer systems that rely on Bayes' Theorem, rather than the person, to integrate large amounts of data.

A research study was conducted to test whether tactical intelligence analysis could be improved by using an interactive Bayesian inference aid. It was found that it could be; both experienced and inexperienced (but trained) tactical intelligence analysts demonstrated significantly improved discrimination between the most and least likely opposing force (OPFOR) courses of action as determined by the majority of analysts when they worked with an interactive Bayesian inference aid than when unaided. Furthermore, analysts working with the aid specified a final rank order for the courses of action that was more consistent with the implications of the intelligence data, as determined by the assessed likelihood ratios of both aided and unaided analysts alike, than did analysts not working with the aid.

Future research efforts should focus on replicating the results reported herein with more complex tactical intelligence problems. In particular, complexity should vary in three general ways: by varying characteristics of intelligence data, by linking together tactical intelligence analysis with

subsequent data collection and tactical decision making, and by more generally representing the analysts' working environment.

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IMPROVING TACTICAL INTELLIGENCE ANALYSIS: A DEMONSTRATION

1.0 INTRODUCTION

Tactical intelligence analysis necessarily depends on human judgment, for analysts must continuously revise estimates regarding the intent of opposing forces (OPFOR) on the basis of newly collected intelligence data. Adelman, Donnell, and Phelps (1981) used Bayes' Theorem as a conceptual framework for representing the subjective revision process inherent in tactical intelligence analysis. By doing so, the large body of psychological research on Bayesian inference was brought to bear on tactical intelligence analysis. This research strongly suggests that tactical intelligence analysis can be improved by using Bayesian inference aids.

Bayes' Theorem is shown in equation [1]. H_1 and H_2 refer to the hypotheses under investigation, which in tactical

$$\underbrace{\frac{P(H_1|D)}{P(H_2|D)}}_{\text{(Prior Probabilities)}} \times \underbrace{\frac{P(D'|H_1,D)}{P(D'|H_2,D)}}_{\text{(Likelihood Ratio)}} = \underbrace{\frac{P(H_1|D',D)}{P(H_2|D',D)}}_{\text{(Posterior Probabilities)}} \qquad [1]$$

intelligence analysis are the OPFOR courses of action (COAs). D refers to the data collected prior to the newly collected intelligence data, which is represented by D'. The ratio of prior probabilities $P(H_1|D)/P(H_2|D)$ indicates the relative

likelihood of H_1 and H_2 (the possible OPFOR courses of action) prior to the newly collected data. The ratio of conditional probabilities $P(D'|H_1,D)/P(D'|H_2,D)$, called a likelihood ratio, indicates the extent to which the new data supports each course of action, for it represents the probability of observing that datum (or indication) if the OPFOR were actually following a given course of action, and given all previous data. Finally, the posterior probabilities $P(H_1|D',D)/P(H_2|D',D)$ indicate the revised likelihood of the OPFOR COAs on the basis of all collected intelligence data. As represented here, Bayes' Theorem represents a normative rule based on probability theory for indicating how tactical intelligence analysts should revise their estimates of the relative likelihood of different OPFOR courses of action on the basis of all collected intelligence data.

Extensive reviews of experimental research in which participants' inferences have been compared with those prescribed by Bayes' Theorem, for tasks other than tactical intelligence analysis, can be found in Fischer, Edwards, and Kelly (1978), Rapoport and Wallsten (1972), and Slovic and Lichtenstein (1971). This research strongly suggests that when given new information, analogous to collected intelligence data, people have considerable difficulty making judgments consistent with Bayes' Theorem. In general, people have been found to revise their posterior probabilities as to the likelihood of alternative hypotheses in the same direction as Bayes' Theorem, but they do not revise them far enough. Such "conservatism" in judgment occurs because people extract less certainty from the data than they should. This finding could have great implications for tactical intelligence analysis, which is a sophisticated Bayesian inference task. If tactical intelligence analysts are conservative information processors, then they are not drawing implications from the data as fast as they

could be with Bayes' Theorem. Their estimates about the relative likelihood of different OPFOR courses of action may well be suboptimal because they will not have sufficiently revised their opinions to take full account of the certainty in the collected data. Consequently, the entire analysis process will not convey as much information to friendly commanders as it could, thereby reducing their time for tactical decision planning and implementation.

General inference aids, called Probabilistic Information Processing (PIP) systems, have been developed to ensure that human judgment is consistent with Bayes' Theorem. In the formulation proposed by Edwards, Lindman, and Phillips (1965), people were tasked with identifying relevant hypotheses, information sources that could discriminate between these hypotheses, and the likelihood ratios linking data with hypotheses. In intelligence analysis, this is analogous to specifying the different OPFOR courses of action, the indicators related to each course of action, and the strength of the indicator-COA relationship, respectively. The task of aggregating information across data in PIP systems was assigned to Bayes' Theorem, since previous research had indicated that people were conservative information processors. This is analogous to using Bayes' Theorem to integrate the implication of intelligence data used to make the overall tactical intelligence estimate. Initial efforts by Edwards, Phillips, Hays and Goodman (1968), Kaplan and Newman (1966), and Wheeler (1972) all found PIP systems superior to unaided inference; PIP consistently assigned higher posterior probabilities to the true hypotheses.

The research referenced above has not been performed with tactical intelligence analysts. It has been conducted with college students under controlled, experimental conditions

using relatively simple judgment tasks as compared to those faced by tactical intelligence analysts. Therefore, one cannot be certain that experienced intelligence analysts would exhibit the same inconsistencies and limitations in judgment exhibited in the cited research. There is, however, reason to suspect that they will. "Conservatism" is the result of people's inability to intuitively integrate large amounts of uncertain information according to a complex normative rule, Bayes' Theorem. Research by Tversky and Kahneman (1974) has shown that people use simpler heuristics instead of Bayes' Theorem to integrate the data. There appears to be no reason why intelligence analysts should be able to perform this complex cognitive task any better than college students, for they receive no training in using Bayes' Theorem to integrate intelligence data. Conservatism on the part of tactical intelligence analysts could well result in suboptimal estimates of the relative likelihood of possible OPFOR courses of action, thereby reducing the time available for tactical decision making and implementation by friendly commanders. The research cited above suggests that conservatism can be reduced by using PIP systems that rely on Bayes' Theorem, rather than the person, to integrate large amounts of data.

This report describes a research study conducted by Decisions and Designs, Inc. (DDI), in conjunction with the Army Research Institute (ARI) and the U.S. Army Intelligence Center and School (USAICS). The purpose of the study was to test whether tactical intelligence analysis could be improved by using an interactive Bayesian inference aid. The study was performed with experienced tactical intelligence analysts (officers and enlisted personnel) and inexperienced but trained analysts (officers who had completed their training at USAICS). Two hypotheses guided the study. The first hypothesis was that experienced and inexperienced analysts working with the aid

would be better able to discriminate between the most and least likely OPFOR courses of action than analysts working without the aid. The second hypothesis was that this improved performance would be the result of significantly less conservatism with than without the interactive Bayesian aid.

To test these hypotheses, the analyses focused on the extent to which the relative likelihood estimates for the OPFOR COAs changed after receiving intelligence data favoring two of the four COAs in the representative tactical intelligence problem used in the study. The first hypothesis would be confirmed by finding that aided analysts, both experienced and inexperienced alike, had significantly higher posterior probabilities than unaided analysts for the OPFOR courses of action considered most likely by the majority of analysts. The second hypothesis would be confirmed by finding that aided analysts had a significantly smaller difference between their theoretical (i.e., Bayesian) and actual (i.e., assessed) posterior probabilities than did unaided analysts. Taken together, these findings would strongly suggest that tactical intelligence analysts are significantly less conservative and, therefore, significantly better able to differentiate between the more and less likely OPFOR courses of action when they can use an interactive PIP system that employs Bayes' Theorem to integrate uncertain data. Discussions with experienced tactical intelligence analysts indicated that such a finding would have significant implications for improving tactical intelligence collection and analysis.

The remaining sections of this report detail the various elements of the research study. Section 2.0 describes the technical approach used in implementing the study. Section 3.0 presents the results of the analyses explicitly designed to test the two hypotheses guiding the study. Section 4.0 presents

the results of analyses designed to test whether aided and unaided analysts differed on other measures. Section 5.0 presents data on how individual analysts used the aid to revise their opinion of OPFOR intent. Finally, Section 6.0 presents the conclusions and recommendations for future research.

2.0 TECHNICAL APPROACH

This section describes, in turn, (1) the general design of the study, (2) the general background of the tactical intelligence analysts who participated in the study, (3) the tactical intelligence exercise they worked on, (4) the interactive Bayesian inference aid (or PIP system) that some of the participants used when working the problem, (5) the different procedures followed by participants in the different research conditions, and (6) the statistical analysis used to test the hypotheses guiding the study.

2.1 General Design

Two factors were manipulated in performing the research reported herein: (1) whether or not the participants used an interactive Bayesian inference aid when working the problem, and (2) whether or not the participants were experienced tactical intelligence analysts. The factors were crossed with each other, resulting in the following four conditions: experienced aided, experienced unaided, inexperienced aided, and inexperienced unaided. Each participant estimated the relative likelihood of the four possible OPFOR courses of action after reading the scenario, but prior to receiving intelligence data (i.e., messages), and again after receiving all the data. The study focused on the extent to which, under each of the four conditions, the relative likelihood estimates for the OPFOR courses of action changed after participants received the data.

It is important to point out that, in practice, tactical intelligence analysts are usually not required to estimate the relative likelihoods of the different OPFOR courses of action,

although on occasion they may be asked to do so by the friendly commander. What they are required to do, either verbally or through routinely submitted summary reports, is to rank order the possible OPFOR courses of action and to keep the commander informed of significant OPFOR activity. The study took into account these operational requirements in the following two ways: first, by having all participants answer three behavioral questions after each message and, second, by having them write, after the final message, a summary report indicating the rank order of the OPFOR courses of action (from most to least likely) and the reasons for their position. It is, of course, quite possible for tactical intelligence analysts to be more or less conservative in their subjective estimates about the relative likelihood of different OPFOR courses of action without that variance affecting (1) the final rank order given to the OPFOR courses of action, (2) the quality of their summary report, or (3) their behaviors after each message.

2.2 Participants

There were two groups of research participants, those who were experienced tactical intelligence analysts and those who were not. Twelve experienced analysts participated; three were instructors at USAICS and nine were practicing analysts in the Washington, D.C. area, either at the Intelligence and Security Command (INSCOM) or the Intelligence Threat and Analysis Center (ITAC). All eighteen inexperienced analysts were Army officers who had just completed training at USAICS.

2.3 Research Exercise

All research participants worked through an abridged version of a training exercise developed by the U.S. Army

Command and General Staff College. The exercise is called "Operation Jayhawk: Control and Coordination of Division Operations." The participants' task during the research study was to estimate the relative likelihood of four OPFOR avenues of approach for attacking U.S. forces. This estimate was to be based on (1) background information about U.S. and OPFOR force composition and disposition, as well as terrain and weather considerations, and (2) ten messages representing intelligence data about OPFOR activity collected sequentially over a two-day period. The messages varied in length and diagnosticity, i.e., the extent to which they supported one OPFOR course of action over another, but they generally supported COAs #2 and #3. Each participant had a map of the area under consideration and a transparent acetate overlay so that force composition and disposition, key military terrain features, and reported OPFOR activity could be recorded. (The actual background scenario and messages can be found in Appendix A.)

2.4 The Bayesian Inference Aid

A simple Bayesian inference aid (or PIP system) was developed by the research team and DDI computer scientists and implemented on an IBM 5110/20 portable computer. Discussions and pretesting prior to the study clearly indicated that tactical intelligence analysts would never use the aid in practice, no matter what the research findings, if they could not revise the posterior probability estimates generated by it. Consequently, the aid was designed to be a highly interactive one that permitted the user to modify the aid's output and to see the implications of those modifications.

The aid is implemented through a four-step procedure. (To assist the reader in understanding the description that follows, Appendix B presents computer printouts showing how one of the

experienced analysts used the interactive Bayesian aid to complete this four-step sequence.)

(1) The tactical intelligence analyst first defines the number (n) (in this case, n = 4) OPFOR courses of action under consideration.

(2) The analyst then enters the relative likelihood of the COAs on the basis of all prior information. This is accomplished in two steps. First, the analyst rank orders the COAs from most to least likely; second, the analyst specifies the prior odds, that is, how many times as likely the most likely COA is than each of the other COAs. The aid then computes the prior probabilities for the COAs such that they sum to 1.0. The analyst can either accept or change these probabilities. If the prior probabilities are changed, the aid computes the prior odds that the analyst would have had to have given to result in the specified probabilities. The analyst can then modify these new prior odds and see the implied prior probabilities, modify the probabilities directly (the aid ensures that they sum to 1.0) and see the implied prior odds, or revise neither the prior odds or probabilities. This step ends when the analyst accepts a set of prior probabilities; these are the only prior probabilities and odds that the aid uses and stores for subsequent consideration.

(3) For a given datum, the analyst enters a brief title summarizing the message. The analyst then rank orders the COAs on the basis of how likely one is to see that datum for each COA. The COA ranked first is the COA for which one would be most likely to see the datum; the COA ranked last is the COA for which one would be least likely to see that datum. After rank-ordering the COAs in terms of the likelihood of the datum, the analyst then specifies how many times as likely one

is to see the datum for the most likely COA as compared to each of the other COAs.

These numbers represent the likelihood ratios in Bayes' Theorem. Examination of equation [1] in the introduction to this report shows that they represent a ratio of two conditional probabilities, that is, $P(D'|H_1,D)/P(D'|H_2,D)$. This ratio indicates the relative likelihood of receiving the datum (D') given that the OPFOR was actually pursuing COA#1 (H_1) versus COA#2 (H_2), and taking into account all previous data (D). If the ratio is greater than 1.0, then given all previous data it is more likely to observe the datum if the OPFOR is pursuing COA#1 than if they are pursuing COA#2. If the ratio is less than 1.0, then one is more likely to receive the datum if the OPFOR is actually pursuing COA#2. If the ratio equals 1.0, then the datum is just as likely to have been generated by COA#1 or COA#2. Since the aid asks the analysts first to rank order the COAs on the basis of how likely they are to generate the datum D', and then to make the ratio comparisons, the ratios have to be greater than or equal to 1.0. The larger the likelihood ratio between two COAs, the more diagnostic the datum for differentiating between COAs. In tactical intelligence analysis terms, the higher the likelihood ratio, the better the indication of OPFOR intent.

(4) Once the analyst specifies the likelihood ratios, the aid uses Bayes' Theorem to compute the posterior odds and probabilities for the OPFOR COAs. It is important to point out to readers who are not familiar with Bayes' Theorem that the posterior odds and likelihood ratios are distinctly different terms in Bayes' Theorem. The posterior odds indicate the relative likelihood of two COAs, given all the data; the likelihood ratio indicates the relative likelihood of the datum (D'), given the two COAs and all previous data (D). It

is quite possible to have a high likelihood ratio implying that a datum was probably generated by an OPFOR COA that, given all the data, would probably not be followed by the OPFOR (i.e., have a low posterior probability); this might occur, for example, if the OPFOR was trying to deceive the friendly forces.

It is important to point out to readers familiar with Bayes' Theorem that pretesting discovered that tactical intelligence data is conditionally dependent; the probability of datum given a particular COA depends on the set of previously received data. Consequently, participants were told to specify likelihood ratios based on conditional dependence, not conditional independence, which was so often done in previous research.

The analyst can either accept or change the posterior probabilities generated by the aid. If the posterior probabilities are changed, the aid then computes the likelihood ratios that, in conjunction with the prior odds, would have generated the newly specified posterior probabilities. The aid also displays the original likelihood ratios so that the analyst can compare the likelihood ratios implied by the newly specified posterior probabilities with those assessed originally. The analyst now has the opportunity to change the likelihood ratios, thereby generating new posterior probabilities. This iteration continues until the analyst is pleased with the likelihood ratios and posterior probabilities for each datum. The aid uses and stores only the last set of posterior probabilities and likelihood ratios. When a new datum is received, these posterior probabilities now become the prior probabilities in Bayes' Theorem, and the analyst need only generate likelihood ratios for the new datum in order to revise the estimate of the relative likelihood (i.e., the posterior probabilities) of the OPFOR COAs.

2.5 Procedures

The procedures followed by the participating analysts depended on whether the analysts worked with the Baysian inference aid or not. Analysts working with the aid first read the background scenario describing the Jayhawk exercise. After doing so, they used the interactive Bayesian inference aid to help them estimate the prior odds and probabilities for the four OPFOR COAs (called Avenues of Approach in the Jayhawk exercise). Then, the analysts received, in sequential fashion, separate messages describing observed OPFOR activity. For each message, the analysts estimated the likelihood ratios in the manner described in Section 2.4, and the aid calculated the posterior probabilities and odds. The analysts used the aid's interactive capabilities until they were satisfied with the posterior probabilities. Then, they received the next message and repeated the above procedure. Eight inexperienced analysts and seven experienced analysts participated in the aided condition; of the seven experienced analysts, three were instructors at USAISC and four were practicing tactical intelligence analysts from agencies in the Washington, D.C. area.

The procedures followed in the unaided condition depended on whether the participant was an inexperienced or an experienced analyst. The inexperienced analysts in the unaided condition followed the same procedures as the analysts in the aided condition, but they did not use the Bayesian inference aid to help them estimate the prior odds, the likelihood ratios, or the posterior odds. The experienced analysts in the unaided condition just estimated the prior odds and the posterior odds after all ten messages; they did not estimate the likelihood ratios and posterior odds for each message. The procedures in the unaided condition were modified for the experienced analysts for three reasons: (1) few practicing tactical intelligence

analysts in the Washington, D.C. area were available for participation during the time of the study; (2) there were time constraints when working with them; and (3) future implementation concerns required that time be given to letting the analysts gain experience with the Bayesian inference aid after participating in the study. Ten inexperienced analysts and five experienced analysts participated in the unaided condition. (Copies of the forms used to estimate the prior odds, likelihood ratios, and posterior odds can be found in Appendix C.

All participants did two other activities in addition to making the probability estimates described above. First, they answered the following three behavioral questions after each message: (1) Would they request an immediate briefing with the Division Commander? (2) Would they request additional information from Corps? (3) Could they conclude that the OPFOR had selected a primary avenue of approach? Second, after receiving all the messages and estimating their final posterior probabilities, the analysts wrote a summary report rank ordering the COAs from most to least likely and justifying their position. These two additional activities were included in the study in an effort to determine whether the behavior of tactical intelligence analysts (or more accurately, experimental efforts to model that behavior) either depended on the level of analyst's experience or was affected by working with the aid. (A copy of the questionnaire and summary report form can be found in Appendix D.)

Experienced and inexperienced analysts in the aided and unaided conditions received a tutorial on Bayesian inference. Participants in the aided condition also received instruction on using the aid. The researchers monitored the subjects' behavior for the first few messages to ensure that the participants could use the aid correctly. In general, efforts were

made to ensure that participants understood their task, felt free to ask questions, and had sufficient time to complete their work.

2.6 Statistical Analysis

Analysis of Variance (ANOVA) was used to test statistically whether the four conditions (aided-experienced, aided-inexperienced, unaided-experienced, and unaided-inexperienced) differed, in general, in their estimates of the relative likelihood of the four OPFOR COAs. The probabilities for the four COAs could not be used, however, because they were not independent, as required for an ANOVA; one can calculate the fourth probability from the first three since the four probabilities must sum to 1.0. Consequently, odds estimates for three COA comparisons were used instead of probabilities to ensure independence in the ANOVA. In addition, the logarithm of each participant's odds estimate for each of the three COA comparisons was calculated to ensure that the dependent variables were additive (probabilities are multiplicative), as required by an ANOVA.

The following three independent COA comparisons were used in the ANOVA: avenues of approach #2 vs #1, #3 vs #2, and #3 vs #4. These COA comparisons were chosen because preliminary examination of the data clearly indicated that #2 and #3 were the two most likely OPFOR COAs and that #1 and #4 were the two least likely COAs, in the opinion of the majority of the analysts after they had received all ten messages. The selected COA comparisons represent the smallest number of independent comparisons that include all four COAs and, at the same time, permit one to evaluate group differences between (a) the two most likely OPFOR COAs and (b) each of the most likely COAs with at least one of the least likely COAs.

In summary, ANOVA on the logarithms of the odds estimates for COA comparisons #2 vs #1, #3 vs #2, and #3 vs #4 were used to test the hypotheses guiding the research study. The type of ANOVA design depended on the dependent measure (e.g., the posterior odds or the mean rank orders) being analyzed. The particular ANOVA design used in the analysis is described prior to presenting the results for that dependent measure.

3.0 RESULTS: CONFIRMATION OF GUIDING HYPOTHESES

Two hypotheses guided the study. The first hypothesis was that experienced and inexperienced analysts working with the aid would be better able to discriminate between the most and least likely OPFOR courses of action than analysts working without the aid. The second hypothesis was that this improved performance would be the result of significantly less conservatism with than without the interactive Bayesian aid. To test these hypotheses, the analyses focused on the extent to which the relative likelihood estimates for the OPFOR COAs changed after receiving intelligence data favoring two of the four COAs in the representative tactical intelligence problem used in the study. This section presents the results of these analyses with respect to each of the two hypotheses.

3.1 Hypothesis I: Improved Discrimination with the Aid

The following results would support the first hypothesis, that experienced and inexperienced analysts are better able to discriminate between the most and least likely OPFOR COAs with than without the aid: (1) there were no statistically significant differences in the logarithms for the groups' final theoretical posterior odds for the three COA comparisons, indicating that the groups drew the same implications from the data and had similar likelihood ratios for the ten messages; (2) there were statistically significant differences in the logarithms for the groups' final assessed posterior odds, with the aided groups having significantly larger logarithms than the unaided groups for the COA comparisons (particularly for comparisons #2 vs #1 and for #3 vs #4), indicating that aided analysts were better able to use the intelligence data to

discriminate between the most and least likely OPFOR COAs; and (3) there was a significantly larger difference between the logarithms of the assessed posterior and prior odds for the aided than unaided groups, indicating that aided analysts were better able to use the intelligence data to move away from their initial position.

It is important to note that confirming the guiding hypothesis does not necessarily imply that participants using the aid were more accurate than participants not using the aid. Unfortunately, the Jayhawk exercise did not indicate what the relative likelihood of the four OPFOR COAs should be prior to or after receipt of the intelligence data; it neither rank ordered the COAs nor provided prior or posterior probabilities. Since there was no external criterion in the Jayhawk exercise, accuracy could not be measured in the research study.

It was, however, possible to measure the general level of agreement among the participants. Presumably, the analysts should agree, in general, on the most and least likely OPFOR COAs and on the likelihood ratios, regardless of whether or not they use the aid. What is hypothesized to differ is the posterior probabilities; with the aid, they should be much higher for the COAs that, in general, the analysts consider most likely and, conversely, much lower for the COAs that the analysts, in general, consider least likely. Such a finding would suggest that tactical intelligence analysts are better able to differentiate between OPFOR courses of action when they can use a PIP system that utilizes Bayes' Theorem to integrate uncertain data.

3.1.1 Theoretical posterior odds - If the aided-experienced, aided-inexperienced, and unaided-inexperienced groups drew the same implications from the tactical intelli-

gence data in the ten messages, then their assessed likelihood ratios should have been sufficiently similar to result in similar theoretical posterior odds for the three COA comparisons. A one-between-subjects and one-within-subjects ANOVA design was used to test whether the final theoretical posterior odds (i.e., those calculated from the analysts' initially assessed likelihood ratios using Bayes' Theorem) differed for these three groups. The unaided-experienced group did not estimate likelihood ratios, so one cannot calculate their theoretical posterior odds. The three groups represented levels on the between-subjects factor; the three COAs represented levels on the within-subjects factor. The dependent measure was the logarithms of the theoretical posterior odds for the three COA comparisons.

Figure 3-1 presents, for each group, the mean logarithm of the theoretical posterior odds for each of the three COA comparisons. (Note: Throughout the presentation, COA and AOA are used interchangeably because the Jayhawk Exercise refers to the courses of action as avenues of approach.) The larger the logarithm, the more likely the first COA in the pair. The logarithms of the theoretical posterior odds indicate that, on the basis of the assessed likelihood ratios for the ten messages, all three groups considered avenue of approach #2 more likely than #1, #3 more likely than #2, and #3 more likely than #4.

Table 3-1 shows the ANOVA results based on these data. The only significant effect was for avenues of approach (AOA); the logarithms of the theoretical posterior odds for #3 vs #2 were significantly smaller than those for #2 vs #1 or for #3 vs #4, indicating that the analysts thought the messages supported avenues of approach #3 and #2 over #1 and #4. There were no significant group differences. The failure to find a

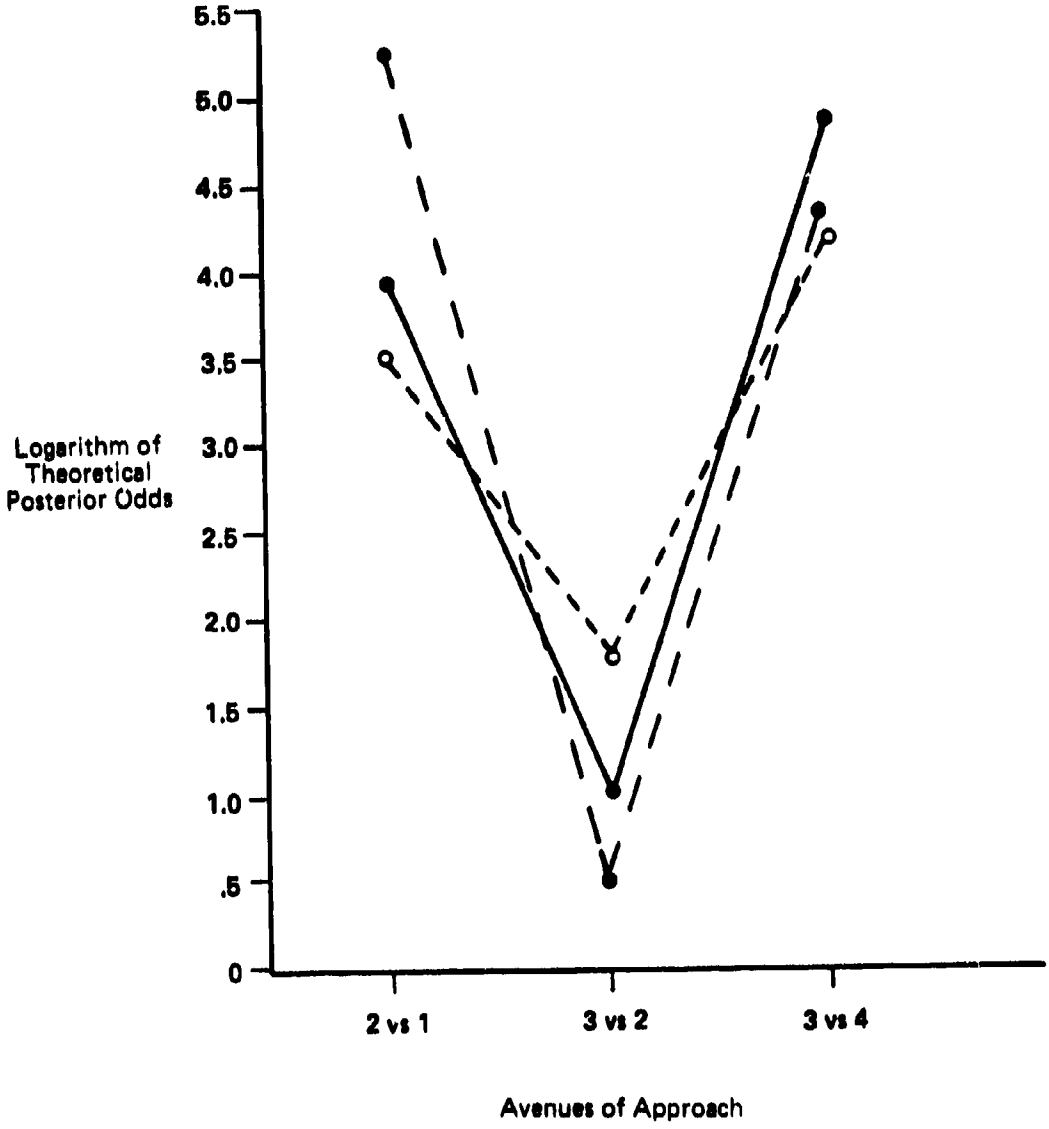


Figure 3-1

THEORETICAL POSTERIOR ODDS

Source of Variation	SS	df	MS	F
Between Subjects				
Group	.665	2	.333	.072
Subject/Group	101.479	22	4.613	
Within Subjects				
AOA	158.998	2	79.499	8.168*
Group x AOA	22.260	4	5.565	.572
Subjects x AOA/Group	428.241	44	9.732	

* = $p < .001$

Table 3-1

ANOVA TABLE FOR THEORETICAL POSTERIORS

significant group effect is consistent with the proposition that the three groups drew similar implications from the data (i.e., they had similar likelihood ratios for the ten messages), and that the data indicated that avenues of approach #3 and (to a lesser extent) #2 were significantly more likely than avenues of approach #1 and #4.

3.1.2 Assessed posterior odds - If the aid improved the performance of tactical intelligence analysts regardless of their level of experience, then the aided-experienced and aided-inexperienced groups should have similar and significantly larger logarithms for the COA comparisons than would the unaided-experienced and unaided-inexperienced groups. Furthermore, based on the results for the theoretical posterior odds, this effect should be most pronounced for COA comparisons #2 vs #1 and for #3 vs #4, since the likelihood ratios assessed by the analysts themselves indicated that the data strongly supported avenues of approach #3 and #2 over avenues of approach #1 and #4.

A two-between-subjects and one-within-subjects ANOVA design was used to test whether the final assessed posterior odds differed for the four groups. The two-between-subjects factors were the level of the analyst's experience and whether or not the aid was used, since each participant was in only one of the study's four groups. The COA factor was within-subjects because the three COA comparisons were made for each participant. The dependent measure was the logarithms of the final assessed posterior odds for the three COA comparisons.

Figure 3-2 presents, for each group, the mean logarithm of the final assessed posterior odds for each of the three COA comparisons. The larger the logarithm, the more likely the first avenue of approach in the pair. A logarithm of zero indicates that the two avenues of approach were equally

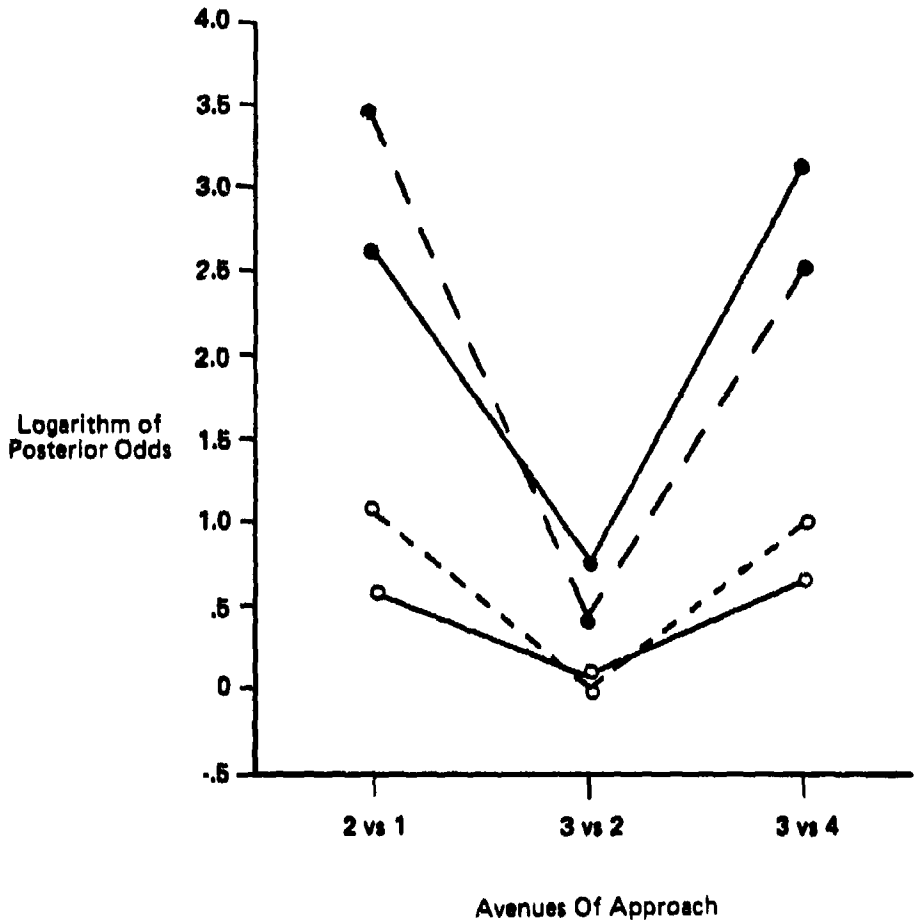


Figure 3-2

POSTERIOR ODDS

likely; a negative logarithm indicates that the second avenue of approach in the pair was the more likely one. The mean logarithms for the COA comparisons made by all four groups were positive. Comparing Figures 3-1 and 3-2 indicates that each group's final assessed posterior odds were in the same direction, although not as extreme, as their theoretical posterior odds.

Table 3-2 shows the ANOVA results based on these data. There was a significant main effect for Aid and for AOA; there was also a significant Aid-by-AOA interaction. The main effect for Aid indicates that there were significant differences in the mean logarithms of the groups' final assessed posterior odds for the COA comparisons. Figure 3-2 shows that the two aided groups had similar and larger logarithms than the two unaided groups for all three COA comparisons, as hypothesized. The Aid-by-AOA interaction indicates that the size of this group difference depended on the COA comparison; the group differences were most pronounced for COA comparisons #2 vs #1 and for #3 vs #4. Finally, the AOA main effect occurred because the logarithms of the final assessed posterior odds for #3 vs #2 were significantly smaller than those for #2 vs #1 and for #3 vs #4, for all four groups. These last two findings were consistent with the results for the theoretical posterior odds, which indicated that the likelihood ratios based on the messages strongly supported avenues of approach #3 and #2 over avenues of approach #1 and #4.

In sum, the results reported in this section confirm the first hypothesis, which was that experienced and inexperienced analysts alike would be better able to discriminate between the most and least likely OPFOR COAs when they worked with an interactive Bayesian inference aid. The next section will show that this improved performance resulted because aided analysts were better able than unaided analysts

SOURCE OF VARIATION	SS	df	MS	F
Between Subjects				
Aid (A)	41.312	1	41.312	19.899**
Experience (E)	.074	1	.074	.036
Aid x Experience (AE)	.550	1	.550	.265
Subject/AE	53.986	26	2.076	
Within Subjects				
AOA	48.569	2	24.285	20.054**
Aid x AOA	11.576	2	5.788	4.780*
Experience x AOA	3.132	2	1.566	1.293
A x E x AOA	1.469	2	.735	.607
Subjects x AOA/AE	62.996	52	1.211	

* = $p < .05$
** = $p < .001$

Table 3-2

ANOVA TABLE FOR POSTERIORS

to use the implications of the messages to move away from their initial position.

3.1.3 Difference between assessed posterior and prior odds - If the aid helped experienced and inexperienced analysts alike to use the intelligence data to move away from their initial position, then the difference in the logarithms of the posterior and prior odds for the aided-experienced and aided-inexperienced groups should be similar and significantly larger than the differences for the unaided-experienced and unaided-inexperienced groups. A two-between-subjects and one-within-subjects ANOVA design was used to test this proposition. The two between-subjects factors were the level of the analyst's experience and whether or not the aid was used; the one within-subjects factor was the COA comparisons. The dependent measure was the difference in the logarithms for the assessed posterior and prior odds for the three COA comparisons.

Figure 3-3 presents, for each group, the mean difference in the logarithms for the assessed posterior and prior odds for the three COA comparisons. Positive differences indicate that the posterior odds were larger than the prior odds; negative differences indicate that the prior odds were larger than the posterior odds. Table 3-3 shows the ANOVA results based on these data. Significant main effects were found for the Aid and for AOA; a significant Aid-by-AOA interaction was found too. The Aid main effect indicates that the mean differences in the logarithms of the posterior and prior odds for the aided-experienced and aided-inexperienced groups were similar and significantly larger than the differences for the two unaided groups over all three COA comparisons. The Aid-by-AOA interaction indicates that the size of the difference depended on the COA comparison. Figure 3-3 shows that the difference for the two aided groups was significantly larger

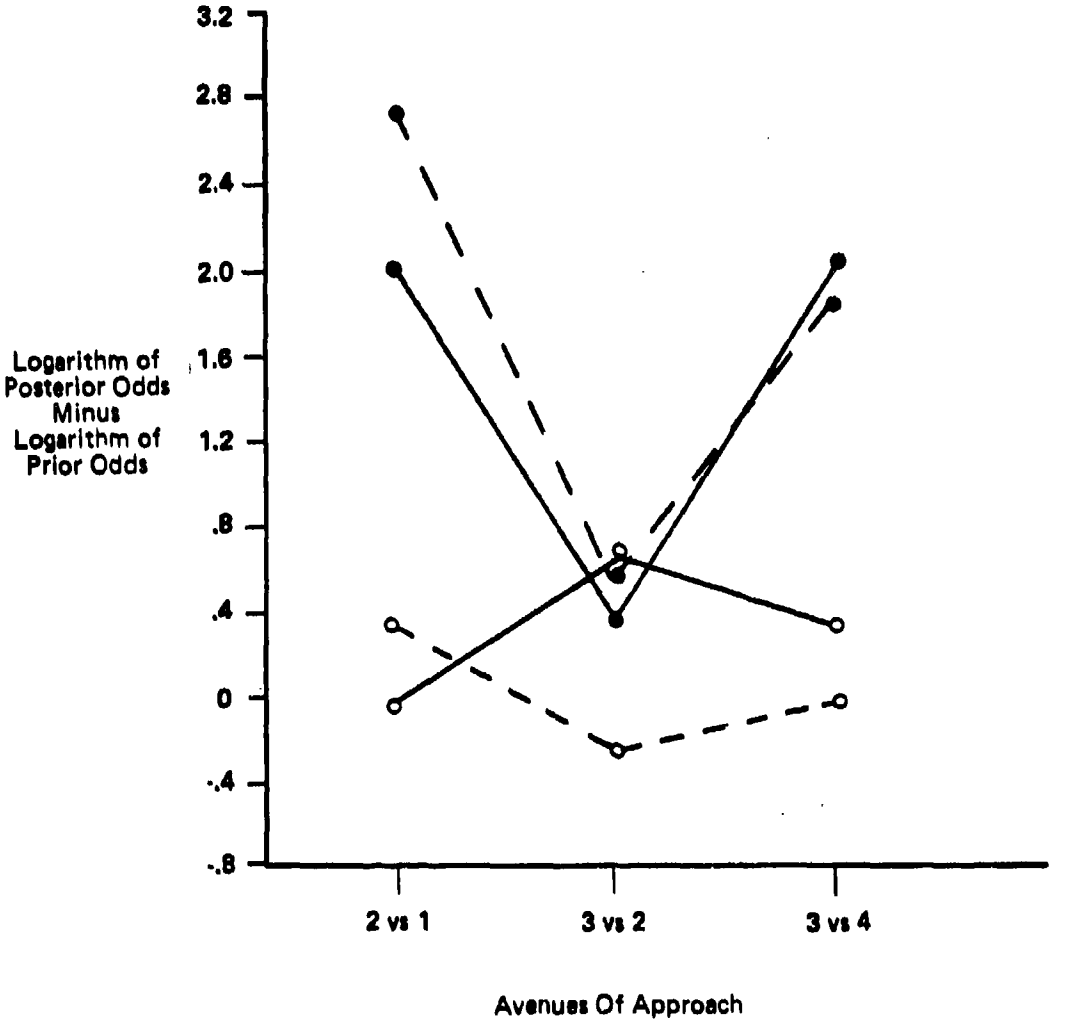


Figure 3-3

DIFFERENCE BETWEEN POSTERIOR AND PRIOR ODDS

SOURCE OF VARIATION	SS	df	MS	F
Between Subjects				
Aid (A)	37.876	1	37.876	14.929**
Experience (E)	.428	1	.428	.169
Aid x Experience (AE)	1.364	1	1.364	.538
Subject/AE	65.966	26	2.537	
Within Subjects				
AOA	17.824	2	8.912	9.245**
Aid x AOA	9.807	2	4.904	5.087*
Experience x AOA	5.331	2	2.666	2.766
A x E x AOA	.828	2	.414	.429
Subjects x AOA/AE	50.123	52	.964	

* = $p < .01$
** = $p < .001$

Table 3-3

ANOVA TABLE FOR DIFFERENCE BETWEEN
POSTERIORS AND PRIORS

than that for the unaided-experienced group only for COA comparisons #2 vs #1 and for #3 vs #4. Finally, the AOA main effect occurred because the mean difference in the logarithms for the assessed posterior and prior odds for #3 vs #2 was, in general, significantly smaller than that for #2 vs #1 or for #3 vs #4.

The results reported herein strongly correspond with those obtained for the assessed posterior odds. Taken together, they indicate that experienced and inexperienced analysts were better able to discriminate between the most and least likely OPFOR COAs when they worked with the Bayesian inference aid because they were better able than unaided analysts to use the implications of the messages to move away from their initial position. The next section presents results that indicate that this increased movement and, in turn, improved performance, occurred because aided analysts were significantly less conservative with than without the aid.

3.2 Hypothesis II: Reduced Conservatism with the Aid

The second hypothesis guiding the study was that aided analysts would be significantly less conservative than unaided analysts. It was hypothesized that this reduced conservatism would result in significantly better discrimination between the most and least likely OPFOR COAs because aided analysts would be revising their posterior odds to be more consistent with the assessed likelihood ratios for the ten messages than would unaided analysts. It has already been shown that aided analysts were more discriminating than unaided analysts. In addition, it has already been shown that there were no statistically significant differences in the theoretical posterior odds of aided and unaided analysts, indicating that aided and unaided analysts alike drew the same implications from the

data and had similar likelihood ratios for the ten messages. All that is now required to confirm the second hypothesis is a significantly smaller difference between the logarithms for the theoretical and actual posterior odds with than without the aid, thereby indicating significantly less conservatism with the aid. Any difference between the logarithms for the final theoretical and assessed posterior odds would indicate some conservatism with respect to Bayes' Theorem; the size of the difference indicates the degree of conservatism.

The theoretical posterior odds are those calculated from the initially assessed likelihood ratios using Bayes' Theorem. The initially assessed likelihood ratios were used in the aided condition because participants only assessed one set of likelihood ratios in the unaided condition. It may be argued that it was inappropriate to use the initially assessed likelihood ratios in the aided condition, for the aid is an interactive one designed to facilitate iteration between the likelihood ratios and the posterior odds; this iteration was expected to result in revisions in the likelihood ratios and, in turn, lower final posterior odds than those calculated using the initially assessed likelihood ratios. Nevertheless, the difference between the logarithms of the final posterior odds and those calculated using the initial likelihood ratios was used in this study to employ a measure of conservatism comparable for both the aided and unaided conditions. If, under the circumstances favoring the unaided condition, the analyses still showed a significantly smaller difference between the logarithms of the theoretical and assessed posterior probabilities with than without the aid, the results would clearly indicate that aided participants were influenced to be significantly less conservative (i.e., more Bayesian) when revising their estimates of OPFOR intent.

A one-between-subjects and one-within-subjects design was used to test whether there were significant differences in the mean difference of the logarithms of the theoretical and assessed posterior odds for the aided-experienced, aided-inexperienced, and unaided-inexperienced groups; the unaided-experienced group did not estimate likelihood ratios and, therefore, were not included in the analysis. The three groups represented levels on the between-subjects factor; the three COA comparisons represented levels on the within-subjects factor. The dependent measure was the difference between the logarithms of the theoretical and actual posterior odds for the three COA comparisons.

Figure 3-4 presents, for each group, the mean difference of the logarithms for the theoretical and actual (final) posterior odds for each of the three COA comparisons. Conservatism is represented by positive numbers, for this indicates that the theoretical posterior odds were larger than the actual posterior odds. All three groups were conservative to some extent since all the numbers are positive. The larger the positive number, the greater the conservatism.

Table 3-4 presents the ANOVA results for these data. The only significant effect was for groups. Figure 3-4 shows that the unaided-inexperienced group was significantly more conservative than the two aided groups. This finding confirms the second hypothesis guiding this study, which was that the performance of experienced and inexperienced analysts alike would be significantly less conservative when they worked with an interactive Bayesian inference aid. This reduced conservatism resulted in significantly better discrimination between the most and least likely OPFOR COAs.

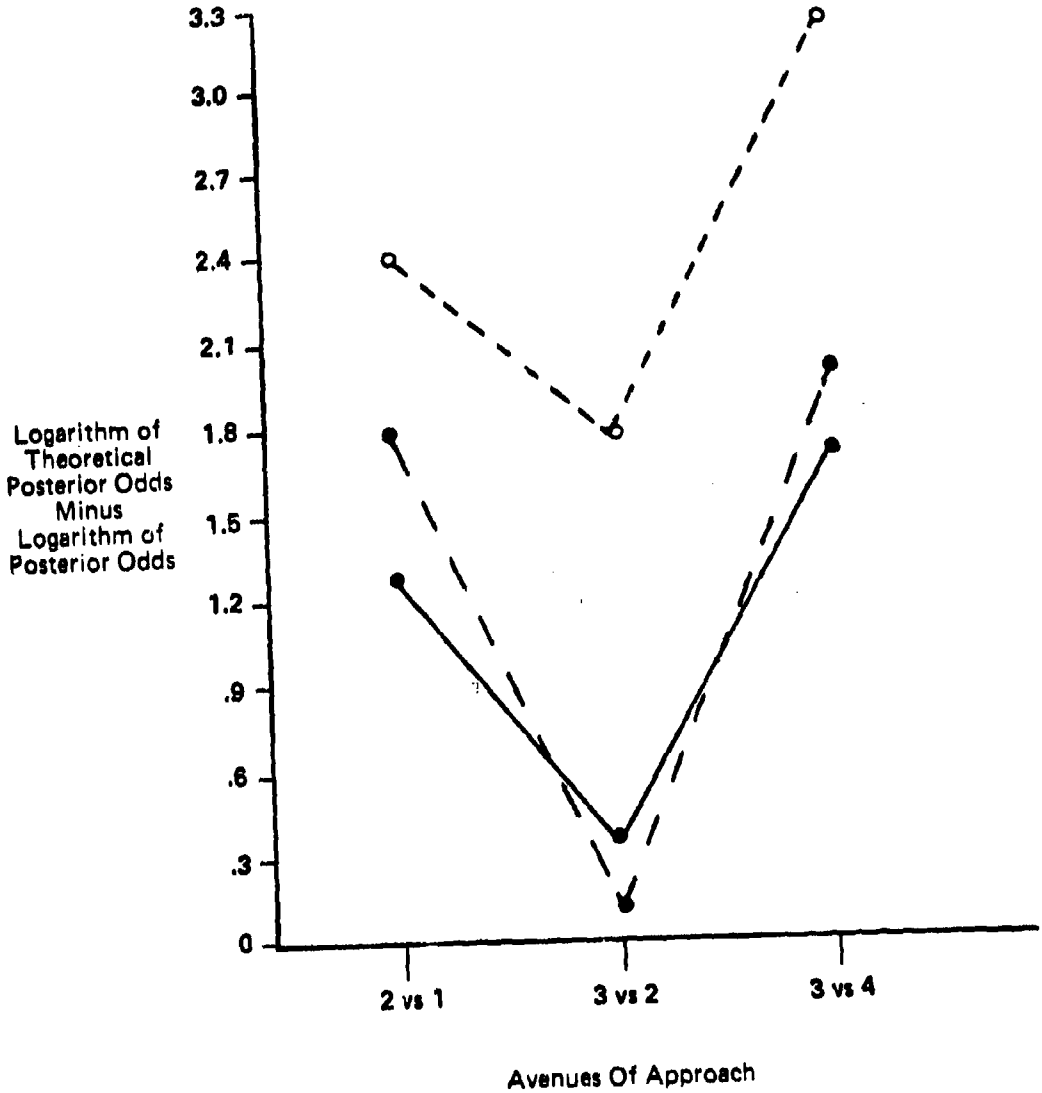


Figure 3-4

DIFFERENCE BETWEEN THEORETICAL AND ACTUAL POSTERIOR ODDS

Source of Variation	SS	df	MS	F
Between Subjects				
Group	29.147	2	14.573	3.472*
Subjects/Group	92.330	22	4.197	
Within Subjects				
AOA	31.933	2	15.967	2.584
Group x AOA	2.535	4	.634	.1023
Subjects x AOA/Groups	271.871	44	6.179	

* = $p < .05$

Table 3-4

ANOVA TABLE FOR DIFFERENCE BETWEEN
THEORETICAL AND ACTUAL POSTERIORS

3.3 Summary

The analyses reported herein confirmed both hypotheses guiding this research study. Experienced and inexperienced analysts were significantly less conservative in their probability estimates when they worked with an interactive Bayesian inference aid; aided analysts had assessed posterior probabilities that were significantly more similar to their theoretical posterior probabilities than did unaided analysts. This reduction resulted in significantly greater discrimination between the OPFOR courses of action considered most and least likely by a majority of the analysts; aided analysts gave AOAs #3 and #2 significantly higher posterior probabilities (and conversely, AOAs #1 and #4 lower probabilities) than did unaided analysts. Figure 3-5 provides a pictorial summary of these results. All statistical analyses were, of course, performed on the logarithms of the odds estimates for the three independent COA comparisons #2 vs #1, #3 vs #2, and #3 vs #4.

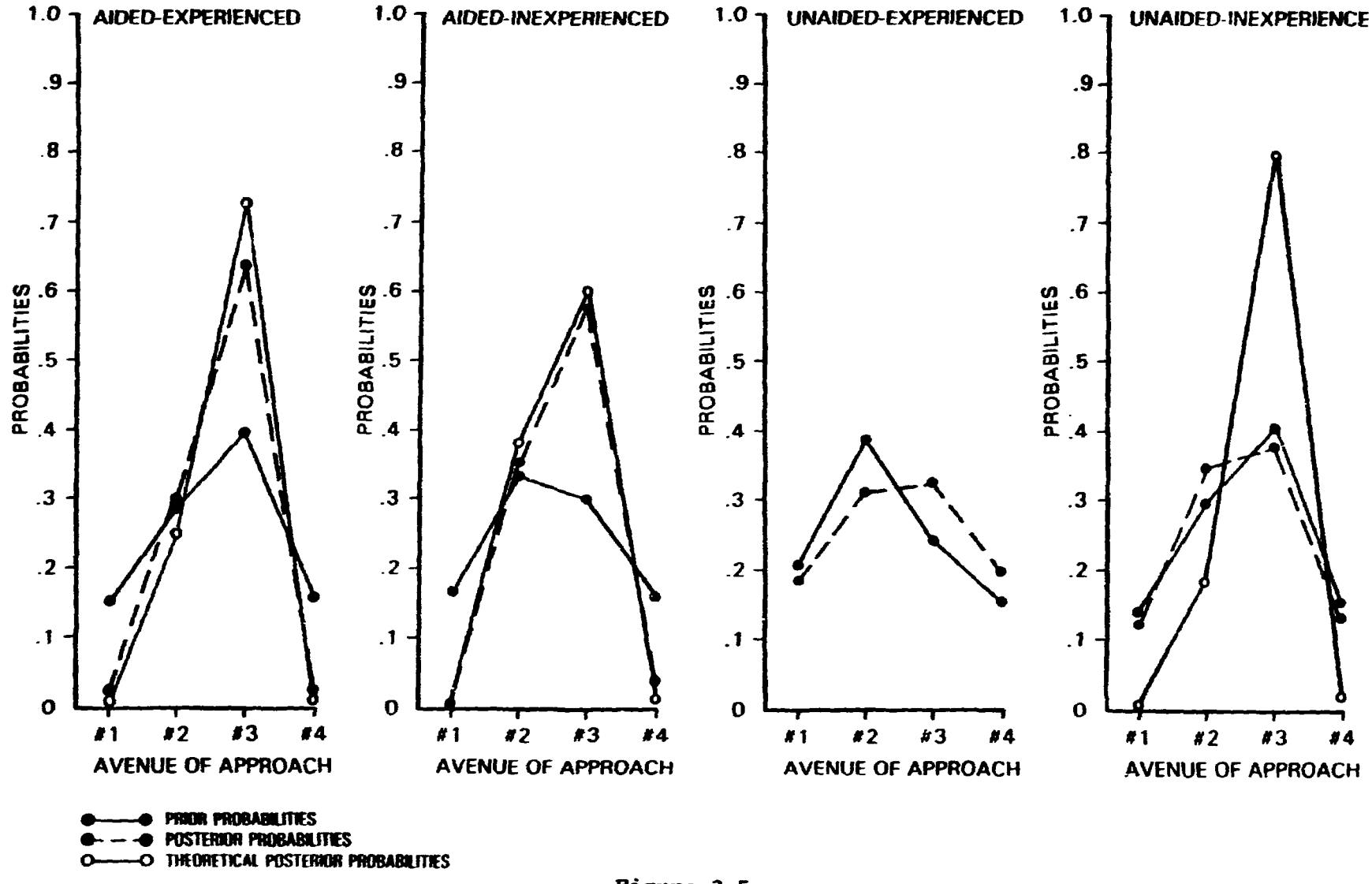


Figure 3-5

SUMMARY OF PRIOR, POSTERIOR AND THEORETICAL POSTERIOR PROBABILITIES FOR EACH GROUP

4.0 ANALYSES OF SUMMARY REPORTS AND BEHAVIORAL RESPONSES

In practice, tactical intelligence analysts are not required to provide probability estimates of the relative likelihood of different OPFOR courses of action. What they are required to do, either verbally or through routinely submitted summary reports, is to provide the rank order of the OPFOR COAs and to keep the commander informed of significant OPFOR activity. The following sections present the results of three analyses designed to determine whether there were significant differences between aided and unaided analysts in the final rank order given to OPFOR COAs, the quality of their summary report, or their behavioral responses to the messages.

4.1 Group Differences: Rank Order of OPFOR Courses of Action

A two-between-subjects and one-within-subjects ANOVA design was used to test whether the four groups assigned different rank orders to the OPFOR COAs when writing their summary reports regarding OPFOR activity. The two between-subjects factors were the level of experience and whether or not the aid was used by the analyst; the one within-subjects factor was the three COA comparisons (#2 vs #1, #3 vs #2, and #3 vs #4). The dependent measure was the difference between the rank orders for the COA comparisons, which is independent, as required for an ANOVA. The rank order for the four avenues of approach could not be used because it is not independent; the rank of the fourth avenue of approach can be determined by knowing the ranks for the other three.

Figure 4-1 presents the mean difference in the rank orders given the three COA comparisons by each of the four groups. When coding the data, the rank orders assigned by the analysts were inverted so that more likely avenues of approach were assigned higher ranks. As a result, positive numbers in Figure 4-1 indicate that the first member of the COA pair was ranked as more likely than the second member of the pair; negative numbers indicate that the second member of the pair was more likely. On the basis of the results presented in Section 3.0 for the final assessed posterior odds, one would expect to see positive numbers for all three comparisons, since #2 was more likely than #1, #3 was more likely than #2, and #3 was more likely than #4.

Table 4-1 presents the results of the ANOVA for the rank order differences assigned to the three COA comparisons by each group. There were significant main effects for the Aid and for the AOA. The Aid main effect occurred because the two aided groups had similar, yet significantly different mean rank differences from the two unaided groups. This difference is particularly noteworthy for the #3 versus #2 comparison. The aided groups have positive numbers indicating that avenue of approach #3 was ranked more likely than #2; in contrast, both unaided groups have negative numbers indicating that they ranked #2 as more likely than #3. The AOA main effect occurred because the mean rank order difference for the #3 versus #2 comparison was significantly smaller than that for the other two comparisons, a finding that directly corresponds to the results presented in Section 3.0.

Taken together with previous findings, these results indicate that, in general, aided analysts not only had different final posterior probabilities for the OPFOR COAs than did unaided analysts, they had different rank orders for them too.

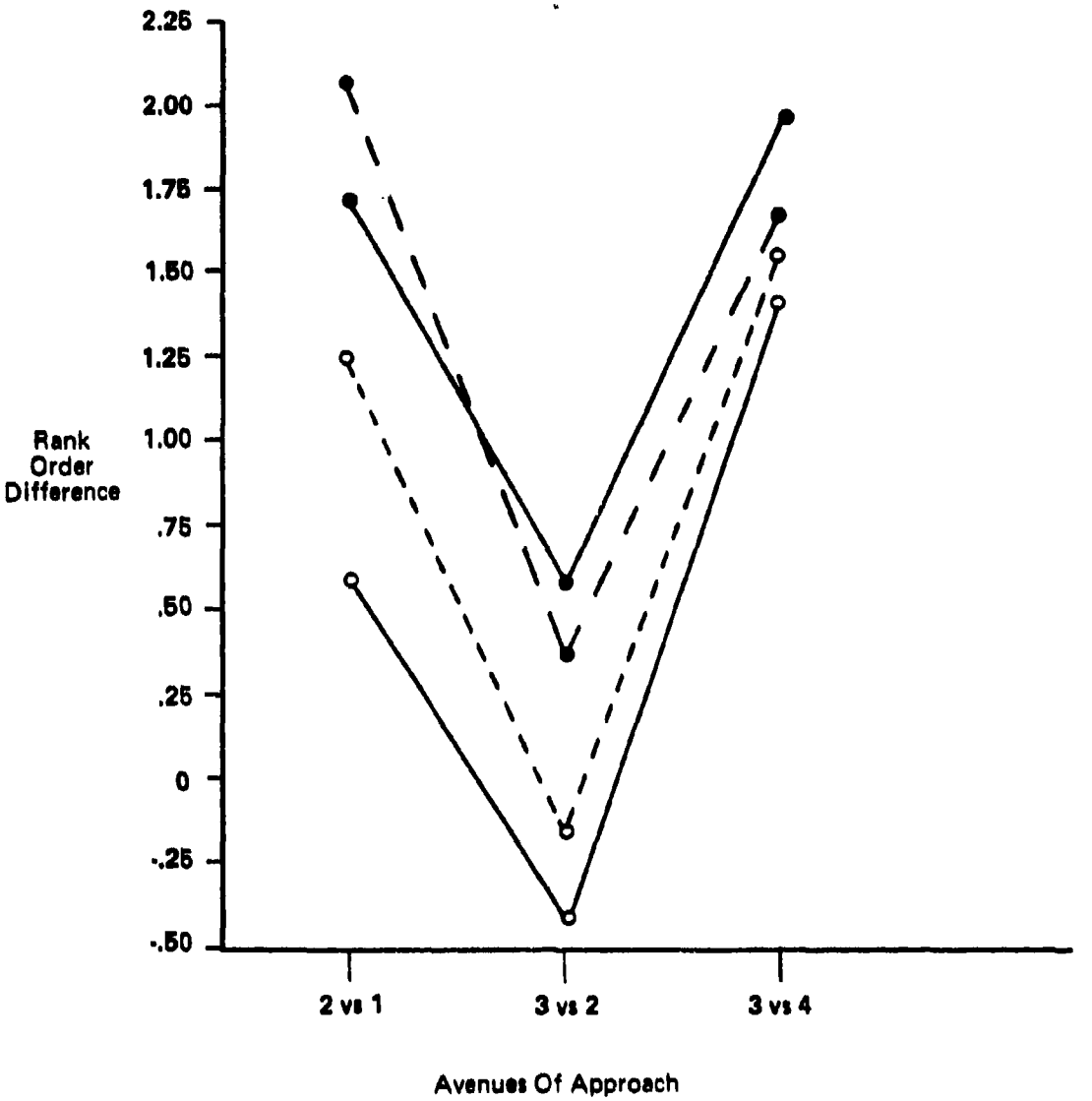


Figure 4-1

RANK ORDER DIFFERENCES

Source of Variation	SS	df	MS	F
Between Subjects				
Aid (A)	6.160	1	6.160	4.688*
Experience (E)	.145	1	.145	.110
Aid x Experience(AE)	.860	1	.860	.654
Subject/AE	34.176	26	1.314	
Within Subjects				
AOA	42.650	2	21.325	13.687**
Aid x AOA	2.636	2	1.318	.846
Experience x AOA	1.194	2	.597	.383
A x E x AOA	.028	2	.014	.009
Subjects x AOA/AE	81.004	52	1.558	

* = p <.05
** = p <.001

Table 4-1

ANOVA TABLE FOR THE RANK ORDERS
GIVEN THE OPFOR COURSES OF ACTION

In particular, aided analysts ranked AOA #3 as most likely, while unaided analysts ranked AOA #2 as most likely. It is important to remember that aided and unaided analysts alike estimated a higher theoretical posterior probability for AOA #3 than that for the other three AOAs combined. This clearly indicates that both aided and unaided analysts thought that the messages strongly supported AOA #3. Yet, only aided analysts were able to convey this implication, in terms of their final rank orders and posterior probabilities.

4.2 Quality of Summary Reports

Six evaluators scored the summary reports on a one-to-seven rating scale, where higher numbers indicate better reports. The evaluators were told to consider the report's clarity and completeness in addition to the quality of its argument supporting the final rank order when making their ratings. The evaluators did not know which AOAs were most or least likely; consequently, the analyst's rank order could not affect the evaluator's rating.

A one-between-subjects and one-within-subjects ANOVA design was used to evaluate statistically whether the ratings differed for the two groups of inexperienced analysts. The two groups represented the between-subjects factor and the six raters, all of whom were familiar with tactical intelligence analysis and all of whom independently evaluated the quality of the summary reports, represented the within-subjects factor. The two groups of experienced analysts were not included because most of them participated after the group of raters had been assembled by the research team.

The mean rating for the aided-inexperienced group was 3.645. The mean rating for the unaided-inexperienced group

was 3.675. Clearly, there were no significant differences in the quality of their summary reports.

4.3 Behavioral Responses

Four issues were addressed for the behavioral questions answered after each message. Three of the four issues focused on whether or not there were significant differences in the proportion of participants within each group who, within the first five messages (1) requested a special briefing with the Division commander, (2) decided that the OPFOR had selected a primary avenue of approach, and (3) concluded that an OPFOR offensive was imminent. The statistical significance of differences in the four groups' responses regarding each of these three issues was assessed by calculating confidence intervals around the proportions for each group; two groups would be significantly different if the proportion for one group did not fall within the confidence interval around the proportion for the other group.

The fourth issue was the relationship between requests for further information and the magnitude of the likelihood ratios. It was found that participants almost always asked for more information. This issue was dropped from the analysis, however, because the researchers concluded that the "Yes-No" choice did not provide a scale with sufficient discrimination to correlate effectively information requests with likelihood ratios.

Table 4-2 presents the results for the three behavioral issues considered in the analysis. None of the differences were statistically significant; consequently, it must be concluded that there were no significant differences in the groups' behavioral responses.

1. Proportion of analysts whose first request for a special briefing with the Division Commander was within the first five messages:

Aided-Experienced (5 out of 5)	100%
Aided-Inexperienced (6 out of 8)	75%
Unaided-Experienced (3 out of 4)	75%
Unaided-Inexperienced (5 out of 10)	50%

2. Proportion of analysts who specified a primary AOA within the first five messages:

Aided-Experienced (2 out of 5)	40%
Aided-Inexperienced (4 out of 8)	50%
Unaided-Experienced (1 out of 4)	25%
Unaided-Inexperienced (5 out of 10)	50%

3. Proportion of analysts who conclude within the first five messages that an attack is imminent within 24 hours:

Aided-Experienced (0 out of 5)	0%
Aided-Inexperienced (1 out of 8)	12.5%
Unaided-Experienced (0 out of 4)	0%
Unaided-Inexperienced (0 out of 10)	0%

Table 4-2

RESPONSES TO BEHAVIORAL QUESTIONS

5.0 INDIVIDUAL DIFFERENCES IN USING THE AID

The results presented in Section 3.0 indicated that, in general, tactical intelligence analysts were less conservative in their final assessed posterior odds estimates when they worked with an interactive Bayesian inference aid. There were, however, considerable differences in the way that individual analysts used the aid. In particular, the fifteen analysts in the aided groups could be classified into four categories: (1) those who acted completely Bayesian in revising their posterior probabilities, (2) those who were slightly conservative, (3) those who were extremely conservative, and (4) those who were in some sense radical, for they made changes in the posterior probabilities for some messages that were so different from the theoretical posterior probabilities that they often resulted in a different final rank order for the OPFOR COAs. Each category is discussed in turn below.

5.1 Bayesian Analysts

One experienced analyst and two inexperienced analysts who used the aid acted completely Bayesian. The experienced analyst accepted the theoretical posterior probabilities for each message; the two inexperienced analysts made minor changes in the theoretical probabilities for a few messages.

Figure 5-1 shows the theoretical and actual posterior probabilities for one of the inexperienced analysts; all inexperienced analysts were coded using the prefix S. The probabilities are represented on the ordinate, and the messages are identified on the abscissa. A plus sign on the abscissa

indicates modified posterior probabilities, thereby permitting one to see how they were changed from the initially calculated posterior probabilities. Figure 5-1 shows that analyst S16 made only one change in the posterior probabilities, and that was to lower slightly the probability for AOA #3 and correspondingly, to raise slightly the probability for AOA #4 after the fifth message. This change had practically no effect overall, for the actual posterior probabilities after the tenth message were essentially identical to the theoretical ones. As a result, S16 has been classified as completely Bayesian.

5.2 Slightly Conservative Analysts

Three experienced and two inexperienced analysts were classified as slightly conservative because their final actual posterior probabilities were noticeably different from their final theoretical posterior probabilities. This occurred because of noticeable modifications in the theoretical posterior probabilities for some of the messages. These modifications were slight and infrequent, however, compared to those of analysts who were classified as extremely conservative. As a result, the actual posterior probabilities of slightly conservative analysts were close to their theoretical posterior probabilities.

Figure 5-2 shows the theoretical and actual posterior probabilities for each message for T2, one of the experienced analysts who was slightly conservative. T2's actual posterior probabilities are noticeably different from the theoretical posterior probabilities. In particular, the actual posterior probability for AOA #3 is lower than the theoretical one and, correspondingly, the actual posterior probabilities for AOAs #1, #2, and #4 are higher than the theoretical ones. This

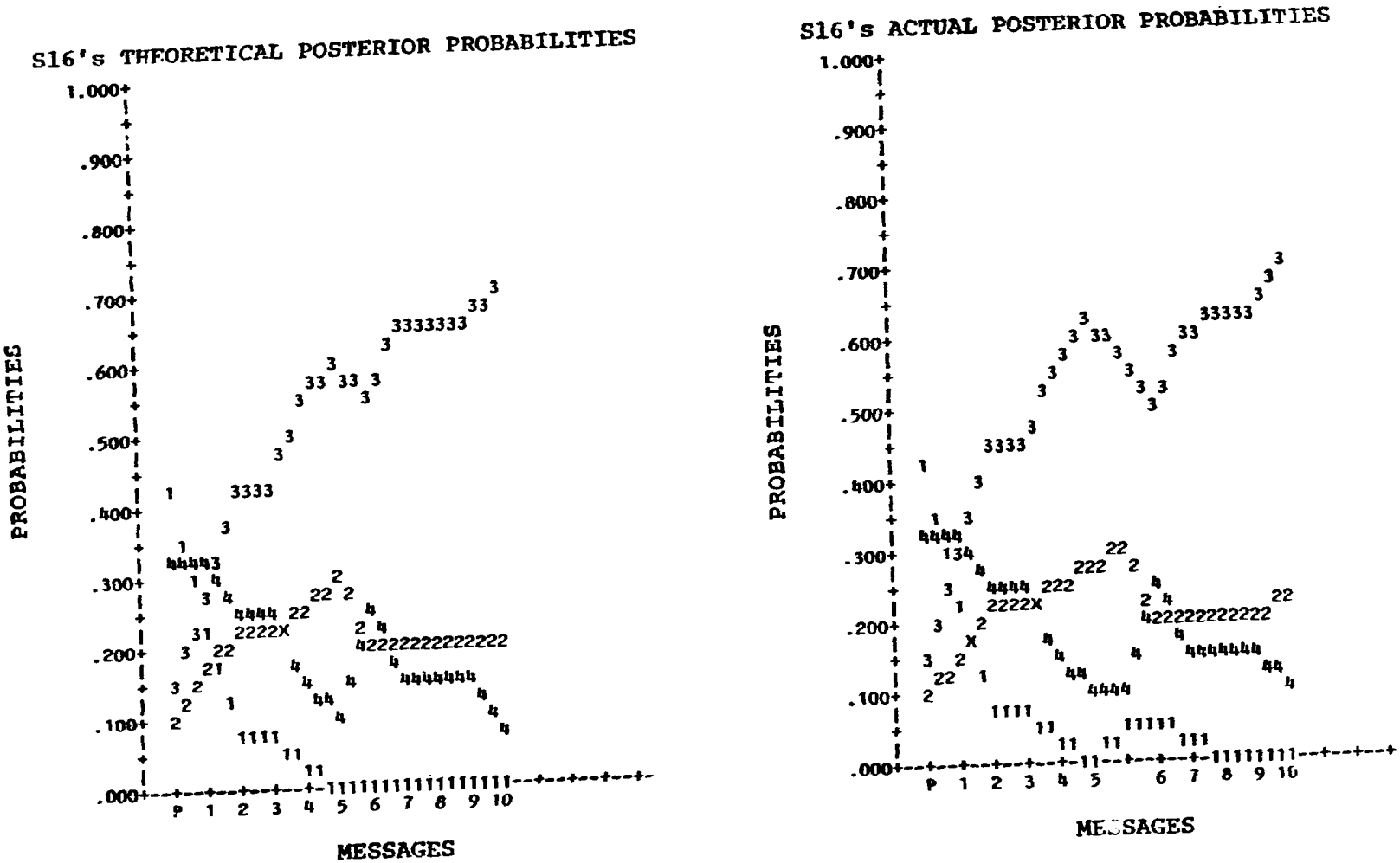


Figure 5-1

THEORETICAL AND ACTUAL POSTERIOR PROBABILITIES
FOR AN ANALYST WHO ACTED BAYESIAN

(Note: Numbers plotted correspond to AOA's; x indicates the same probability for two or more AOA's; + indicates another estimate for the same message.)

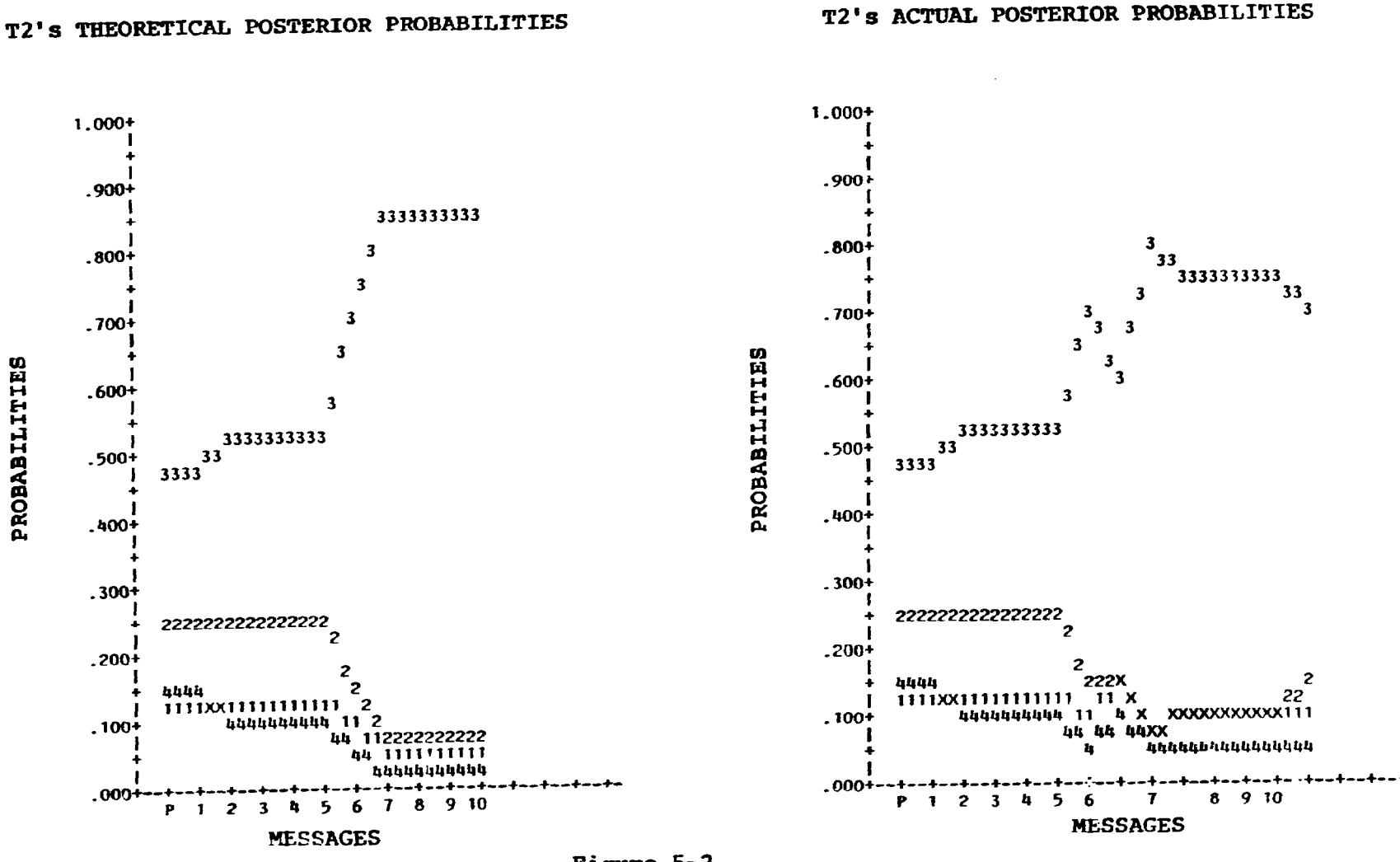


Figure 5-2

THEORETICAL AND ACTUAL POSTERIOR PROBABILITIES
FOR A SLIGHTLY CONSERVATIVE ANALYST

occurred because T2 lowered the initial theoretical posterior probability for AOA #3 for messages #6, #7, and #10. However, because these changes were small, the final actual posterior probabilities were close to the theoretical ones and considerably different from the prior probabilities.

5.3 Extremely Conservative Analysts

Two experienced and two inexperienced analysts were classified as extremely conservative. These analysts made modifications that resulted in final assessed posterior probabilities that were markedly different from their theoretical posterior probabilities and markedly similar to their prior probabilities. As a result, the intelligence data that the analysts themselves said carried implications for OPFOR intent had minimal (if any) effect on their estimates of the relative likelihood of the four OPFOR COAs. The judgments of these conservative analysts was almost completely dominated by the information in the scenario regarding OPFOR and U.S. force and composition factors, and by terrain and weather considerations.

Figure 5-3 shows the theoretical and actual posterior probabilities for T3, one of the experienced analysts who was extremely conservative. Notice that this analyst changed the initial theoretical posterior probabilities for half the messages, and for two of them (messages #1 and #5) they were changed more than once. These changes occurred every time the analyst assessed likelihood ratios that spread out the posterior probabilites; the analyst always moved them close together again. As a result, the final posterior probabilities hardly differed from the prior probabilities. Thus, the intelligence data had practically no effect on the analyst's judgment as to the relative likelihood of the OPFOR COAs.

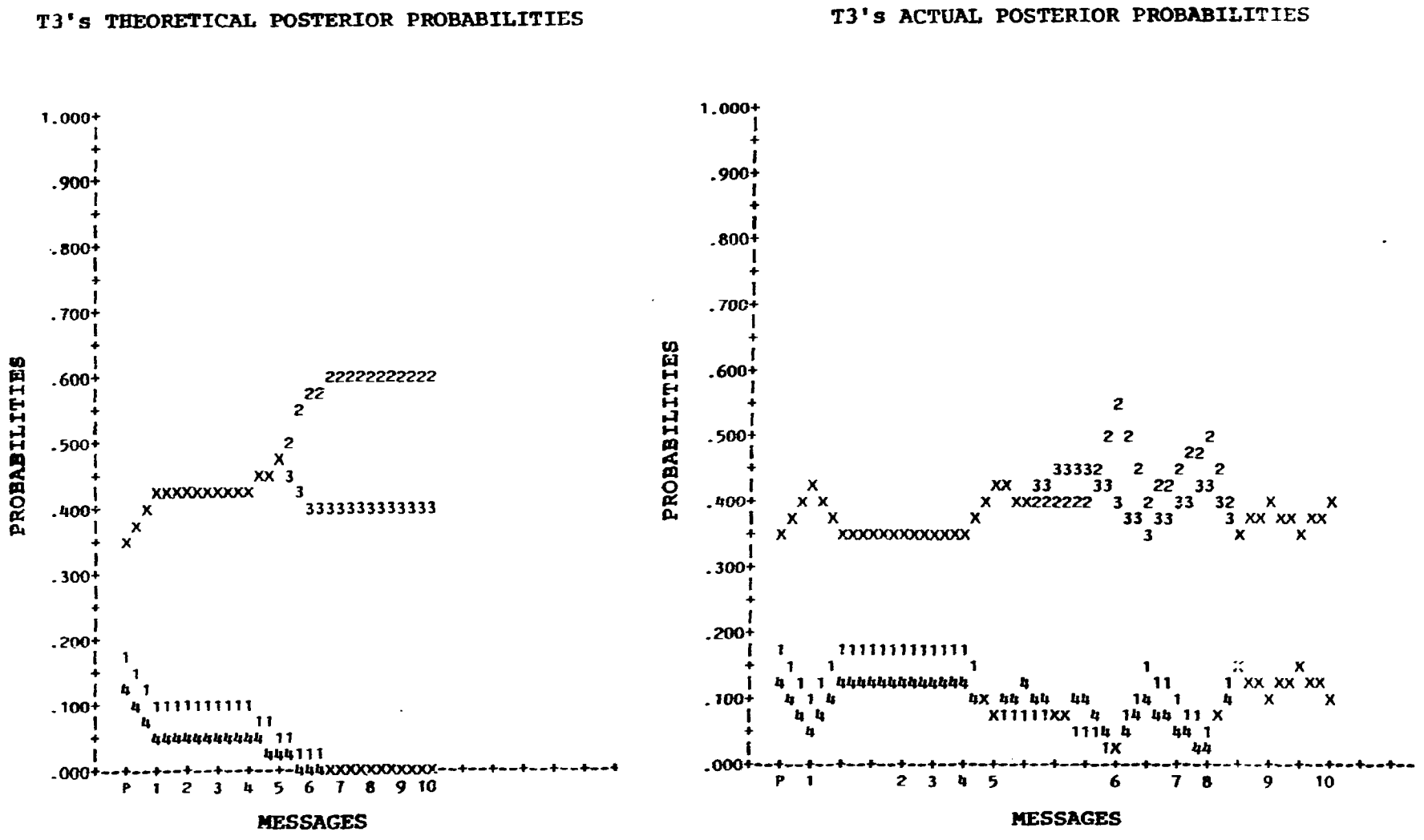


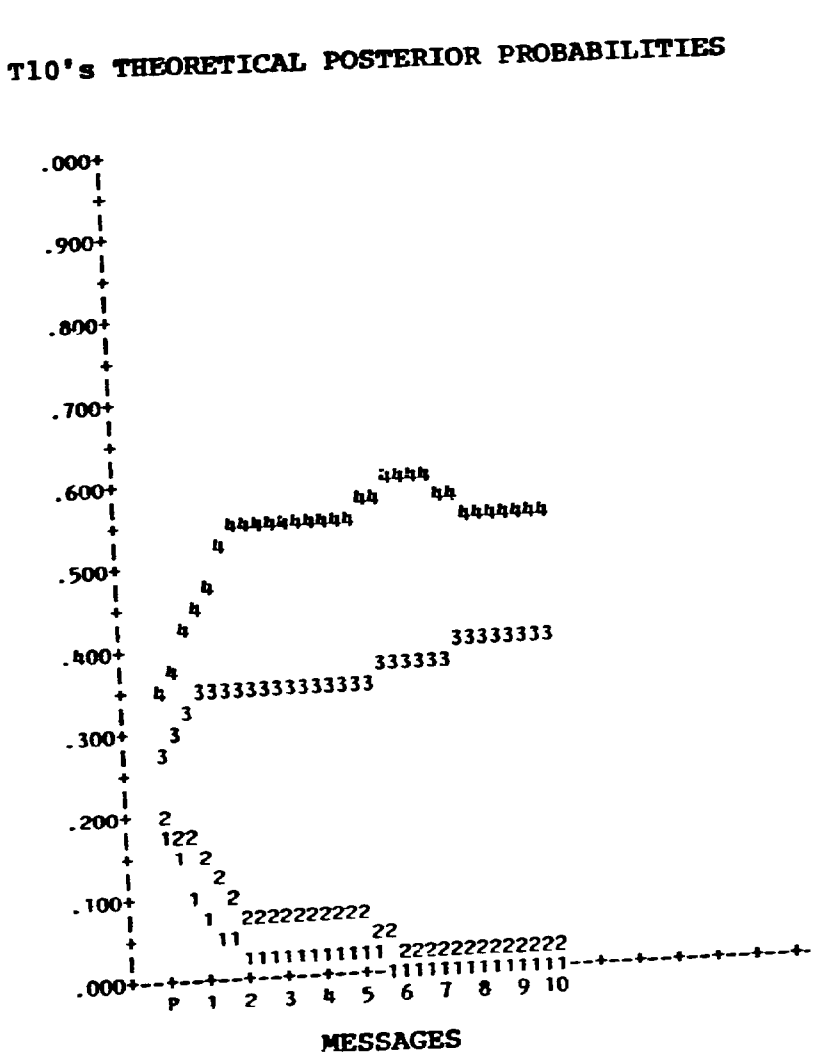
Figure 5-3

THEORETICAL AND ACTUAL POSTERIOR PROBABILITIES
FOR AN EXTREMELY CONSERVATIVE ANALYST

5.4 Radical Analysts

One experienced and two inexperienced analysts were classified as radical analysts. These analysts made changes in their initial theoretical posterior probabilities that were so extreme that they often resulted in final rank orders for the OPFOR COAs that were different from those for their theoretical posterior probabilities. These extreme changes were often made for only one or two messages. When they occurred late in the session, they apparently represented a complete reorientation in the analyst's thinking; two of the three analysts even changed the rank order of the two OPFOR COAs they considered most likely. Although this reorientation in thinking cannot be modeled by Bayes' Theorem, it may well have been facilitated by working with an interactive Bayesian inference aid. Because they were able to see interactively the implications of their judgments (both likelihood ratios and posterior probabilities) for intelligence data over time, these analysts may well have been able to completely re-evaluate their position regarding OPFOR intent.

Figure 5-4 shows the theoretical and actual posterior probabilities for T10, one of the experienced analysts who acted radically. Notice that the theoretical and actual rank orders--and, consequently, posterior probabilities for AOA #3 and #4--are quite different. This difference occurred because T10 changed the initial posterior probabilities for AOAs #3 and #4 for message #7 from .38 and .59, respectively, to .39 and .36, respectively. AOA #3's reduction of .23 probability points primarily benefited AOA #2, which moved from .03 to .20; AOA #1 moved from .01 to only .05. This shift represented a marked reorientation in the analyst's thinking. Prior to the shift, the analyst was saying that the OPFOR's main offensive would be only along the western half of the front (AOA #4 is



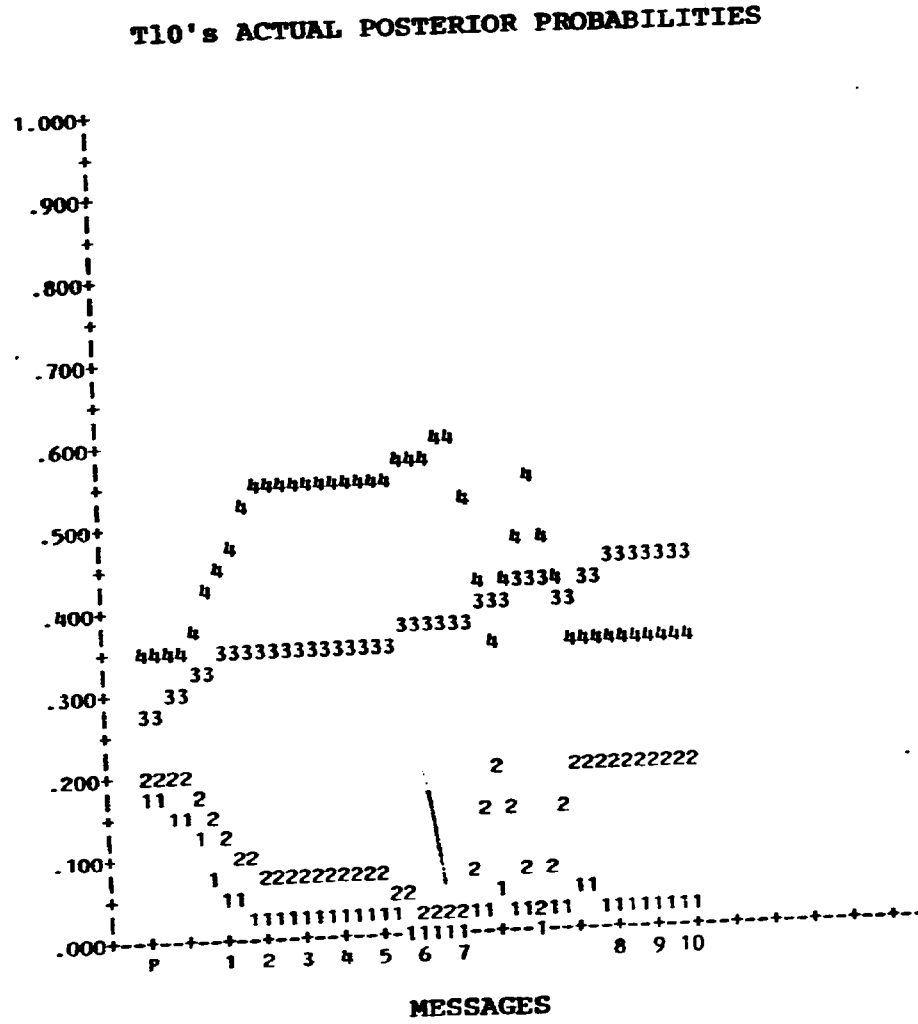


Figure 5-4

THEORETICAL AND ACTUAL POSTERIOR PROBABILITIES
FOR AN ANALYST WHO ACTED RADICALLY

the western-most avenue of approach), but after the shift, the analyst was saying that the offensive would be considerably more toward the center of the front with a distinct possibility of seeing it in the eastern half along AOA #2. A noninteractive Bayesian aid, which was represented by the theoretical posterior probabilities, would not reflect this reorientation in the analyst's thinking. However, an interactive one does reflect it and, as suggested earlier, may even facilitate it by providing analysts with a means of critically examining the implications of their judgment.

5.5 Summary

The results presented in this section indicate that there were substantial differences in the way individual anlaysts used the aid. The analysts were classified into four categories: those who acted completely Bayesian in revising their posterior probabilities, those who were slightly conservative, those who were extremely conservative, and those who were in some sense radical, for they made changes in their initial theoretical posterior probabilities for some messages that were so extreme that they often resulted in final rank orders that were different (or were close to being different) from those based on their final theoretical posterior probabilities.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This research study demonstrated that tactical intelligence analysis could be improved by letting analysts work with an interactive Bayesian inference aid. Experienced and inexperienced analysts working with the aid were better able than unaided analysts to differentiate between the two OPFOR COAs considered most likely and the two OPFOR COAs considered least likely by the majority of analysts. Furthermore, analysts working with the aid specified a final rank order for the OPFOR COAs that was more consistent with the implications of the data according to the assessed likelihood ratios of aided and unaided analysts alike. This improved performance occurred because aided analysts were significantly less conservative in their posterior probability estimates than unaided analysts.

Although, in general, tactical intelligence analysts were less conservative with the aid, there were considerable differences in the way that individual analysts used it. The fifteen analysts in the aided groups could be classified into four categories: those who acted completely Bayesian in revising their posterior probabilities, those who were slightly conservative, those who were extremely conservative, and those who were in some sense radical, for they made changes in the initial theoretical posterior probabilities for some messages that were so extreme that they resulted in final rank orders for the OPFOR courses of action that were different (or were close to being different) from those based on their final theoretical posterior probabilities. The proportion of experienced and inexperienced analysts in each category was quite similar.

There were no significant differences in the quality of the summary reports written by aided or unaided analysts, or in their responses to the behavioral questions. This finding is not surprising. The tactical intelligence analyst's job has a number of related requirements. These requirements include keeping track of OPFOR activity, correlating OPFOR activity with OPFOR intent, and keeping the friendly commander informed of both. When performing the latter requirement, the analyst is trained to emphasize the first requirement, that of providing information about OPFOR activity, and not the second requirement, that of making inferences about OPFOR intent. The summary report and behavioral questions tried to simulate the first requirement; the final posterior probabilities and rank orders of the OPFOR courses of action tried to simulate the second requirement. There is no reason to hypothesize that improved performance in inferring OPFOR intent would necessarily result in improved performance in providing information about OPFOR activity, although such a finding would, of course, be an extremely important one. There is, however, reason to hypothesize that it would result in significant improvements in the intelligence collection process and in the performance of friendly commanders by giving them more time for tactical decision making and implementation. Investigation of these hypotheses were beyond the scope of this study.

Future research efforts should focus on replicating the results reported herein with more complex tactical intelligence problems. In particular, complexity should vary in three general ways: by varying characteristics of intelligence data, by linking together tactical intelligence analysis with subsequent data collection and tactical decision making, and by more generally representing the analysts' working environment. Each form of complexity is considered in turn.

The intelligence data transmitted in the ten messages used in this study were relatively simple and straightforward, for they were perfectly reliable and unambiguous. Actual tactical intelligence data are seldom this way. By making the data unreliable, for example, one is conceptually developing a hierarchical or multi-level Bayesian inference problem, since there are two steps in the analyst's inference process. In the first step, the analyst must evaluate the probability that the datum is reliable, i.e., true. In the second step, the analyst then must evaluate the extent to which the datum supports the different OPFOR COAs. Experimental evidence on hierarchical (or multi-level) Bayesian inference aid is unfortunately scant. Gettys, Kelly, Peterson, Michel, and Steiger (1973) have conducted two relevant studies, however, both of which demonstrated the superiority of a hierarchical, Bayesian inference aid over unaided inference, for task not involving tactical intelligence analysis. In addition, Peterson, Randall, Shawcross, and Ulvila (1975) and Stewart, O'Connor, Frisvold, Hoblitzell, Ragland, and Randall (1980) have developed prototypical hierarchical Bayesian inference aids for tactical and strategic intelligence analysis, respectively; but the relative effectiveness of these aids has not been evaluated in a controlled research study like the one reported herein.

Future research should also investigate the relationship between tactical intelligence analysis and both subsequent (1) data collection and (2) tactical decision making and implementation. To date, no research has systematically studied these relationships. It is hypothesized here that analysts will be able to improve their data collection strategies with Bayesian inference aids because they will be better able to discriminate between the most and least likely OPFOR courses of action. Such discrimination should help analysts select collection sources that more effectively monitor OPFOR activity. It

should also provide the friendly commander with additional time for tactical decision making and implementation. Many of the experienced analysts who participated in the study considered this to be the primary value of using Bayesian inference aids in tactical intelligence analysis. Research is needed to test these hypotheses.

Finally, future research should try to represent more effectively the tactical intelligence analyst's working environment. In their actual environment, analysts work in groups, and they are often barraged with intelligence data over a short time. Although critics might argue that such working conditions make the utilization of Bayesian inference aids infeasible, just the opposite is argued here. Once participating analysts became familiar with the aid, they were able to use it to evaluate quickly the messages in the study. Furthermore, the aid could be streamlined to become a more natural part of the intelligence analysis process, and it can be readily integrated into the computerized intelligence analysis systems being developed by the U.S. Army. Finally, the aid provides a means for analysts (and commanders) to see if they agree in the implications they individually draw from the data; this will facilitate, not hinder, the group's work.

The present study demonstrated that, for a representative tactical intelligence problem, analysts were better able to discriminate between the more and less likely OPFOR courses of action when they used an interactive Bayesian inference aid. It represents an important first step. Considerable future research is required, however, to determine whether this finding will generalize to the analyst's working environment. Discussions with experienced analysts indicated that if it did, it would have significant implications not only for

tactical intelligence analysis and collection, but for tactical decision making and implementation as well.

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APPENDIX A
SCENARIO AND MESSAGES FOR THE RESEARCH EXERCISE

OPERATION JAYHAWK: CONTROL AND COORDINATION OF DIVISION OPERATIONS

Appendix 1 to Advance Sheet. General and Special Situations

1. GENERAL SITUATION

a. Maps.

(1) Map, series USACGSC 250—140, Western United States, sheet 1 (St Joseph—Topeka), edition 1976, 1:250,000 (map A).

(2) Map, series USACGSC 100—131, Western United States, sheet 1 (Lawrence—Leavenworth), edition 1976, 1:100,000 (map B).

(3) Sketch map, Sketch of Corps Defense (app 2 to adv sheet) (map C).

b. Background.

(1) During the summer of 1977, Pakland and Eurlandia reached an agreement that established a mutual balance of forces between the two countries and restricted the strength of each country's combat forces.

(2) Eurlandia, with the help of its allies, has begun a program to upgrade its armed forces and achieve complete equipment modernization prior to implementation of the negotiated agreement.

(3) Pakland interprets this accelerated modernization of Eurlandia armed forces as a threat to its national security and decides that it must attack before Eurlandia achieves a definite military advantage. Pakland strategy is to gain maximum surprise by attacking as soon as possible.

(4) It is anticipated that Central Front, as part of a larger Pakland force, will attack Eurlandia's central region to rapidly rupture initial defenses and secure deep objectives.

2. SPECIAL SITUATION

a. Allied forces. All units of 1st (US) and 2d (US) Corps are located south and east of the area of operations (off the map) where they are currently revising and updating defensive plans in light of an anticipated attack by Pakland forces. The 1st (US) Corps consists of the 52d Mech Div, 23d Armd Div, 312th Sep Mech Bde, and the 201st Armd Cav Regt, and is assigned a defensive sector west of the Missouri River. The corps mission is to defend and destroy enemy forces in sector, retain the dominating high ground to the north of the Kansas River, and establish a covering force to protect forces in the corps main battle area (MBA). The corps commander visualizes a defensive scheme employing the 23d Armd Div and the 52d Mech Div from west to east. Divisions will control the covering force. The 312th Sep Mech Bde, minus a tank and mechanized battalion, will be attached to the 23d Armd Div since this division sits astride the enemy's best avenue of approach into the corps sector. The 201st Armd Cav Regt (—) with one squadron has been attached to the 52d Mech Div to assist that unit in accomplishing its covering force mission. The remaining two squadrons of the 201st Armd Cav Regt have been attached to the 23d Armd Div for the same reason. More than likely the 312th Sep Mech Bde (—) will be used as the control headquarters for the covering force of the 23d Armd Div. On completion of the covering force missions, the 52d Mech Div will release the 201st Armd Cav

Regt headquarters and air cavalry troop, and the 23d Armd Div will release one of the two attached squadrons. Initially corps will have two battalions in reserve. On completion of the covering force mission, the 201st Armd Cav Regt with two battalions and one armored cavalry squadron will be corps reserve.

b. 52d Mech Div. The 52d Mech Div consists of six mechanized battalions, five tank battalions, and its organic cavalry squadron. Additional assets provided by corps to the division include: the 201st Armd Cav Regt (minus two squadrons), a corps artillery group (five battalions); an attack helicopter company; a Hawk battalion (SP); and a combat engineer battalion.

c. 23d Armd Div. The 23d Armd Div consists of six tank battalions, five mechanized battalions, and the organic cavalry squadron. Additional assets provided by the corps to the division include: the 312th Sep Mech Bde, consisting of one mechanized battalion, one tank battalion, and two squadrons from the 201st Armd Cav Regt; a corps artillery group (six battalions); an attack helicopter company; a Hawk battalion (SP); and a combat engineer battalion.

d. Pakland forces.

(1) Packland has deployed major forces into maneuver areas located 30 kilometers north of the international boundary.

(2) Current intelligence indicates that the attack will probably not take place for approximately 2 to 3 days.

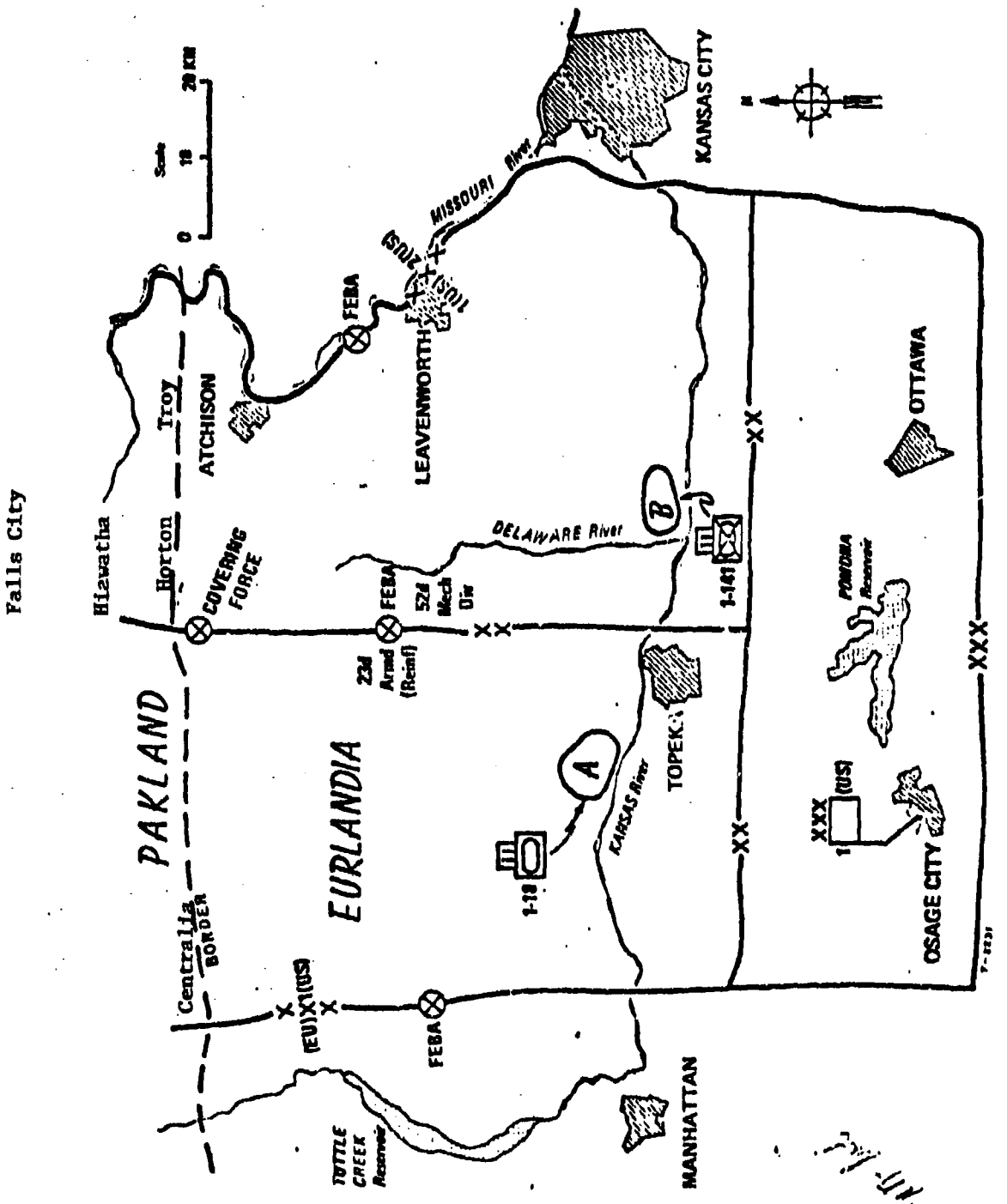
(3) The Front attacking Eurlandia's central region will probably include three armies—the 7th Tk Army, 8th and 10th Gd Tk Armies—and a motorized rifle division in reserve. In the attack, these forces will likely be organized in two echelons, with maximum tank forces employed forward to achieve a rapid breakthrough. Appendix 3 is the Pakland Central Front troop list of maneuver units.

(4) Pakland is expected to have air superiority initially; however, allied air forces would be able to achieve local air superiority for limited periods of time. Indications are that nuclear weapons will not be used in the attack.

(5) Additional intelligence is included in Annex B, Intelligence, to 1st Corps OPLAN 15.

OPERATION JAYHAWK: CONTROL AND COORDINATION OF DIVISION OPERATIONS

Appendix 2 to Advance Sheet. Sketch of Corps Defense (Map C)



OPERATION JAYHAWK: CONTROL AND COORDINATION OF DIVISION OPERATIONS

Appendix 3 to Advance Sheet. Pakland Central Front Troop List of Maneuver Units

1. 7th Tk Army
   - 19th Tk Div
   - 20th Tk Div
   - 21st Tk Div
   - 26th Tk Div
   - 30th Mtz Rifle Div
   - 7th SSM Bde
   - 7th AD Regt
   - 7th Arty Bde
   - 7th Engr Regt
   - 7th Pon Brg Regt
   - 7th Aslt Crossing Bn

2. 8th Gd Tk Army
   - 9th Gd Tk Div
   - 10th Tk Div
   - 23d Gd Tk Div
   - 5th Mtz Rifle Div
   - 8th SSM Bde
   - 8th AD Regt
   - 8th Arty Bde
   - 8th Engr Regt
   - 8th Pon Brg Regt
   - 8th Aslt Crossing Bn

3. 10th Tk Army
   - 24th Gd Tk Div
   - 25th Tk Div
   - 31st Mtz Rifle Div
   - 10th SSM Bde
   - 10th AD Regt
   - 10th Arty Bde
   - 10th Engr Regt
   - 10th Pon Brg Regt
   - 10th Aslt Crossing Bn

4. 33d Mtz Rifle Div

NOTE: This is a partial troop list.

Appendix 6 to Advance Sheet. Extract of Corps Analysis of Area of Operations

(Classification)

Reference: Map, series 250-140, WESTERN UNITED STATES (ST JOSEPH--TOPEKA), edition 1976, 1:250,000 (map A).

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2. GENERAL DESCRIPTION OF THE AREA

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b. Terrain.

(1) Relief and drainage systems. The area under study consists of a plateau that varies in elevation from 305 to 366 meters. Two low ridges run generally northwest to southeast, one midway between STRANGER Creek and the MISSOURI River and one between STRANGER Creek and the DELAWARE River. Another ridge runs generally north to south along highway 75 between the DELAWARE River and SOLDIER Creek. Changes in relief are gradual except in streambeds and along the banks of the MISSOURI River. The principal streams within the area, other than the rivers, are STRANGER Creek, SOLDIER Creek, VERMILLION Creek, and CROSS Creek, which flow south into the KANSAS River. The KANSAS River flows through a wide, flat valley in a flat-bottomed channel with nearly vertical sandy banks. The channel from the junction of the DELAWARE River to the junction with the MISSOURI River averages 165 meters wide and 2 meters deep; its current velocity is .85 meter per second. The MISSOURI River meanders through a wide, flat valley with high bluffs along each side of the valley. The river averages 140 meters wide in our area, and though the depth varies, a 2-meter-deep channel is kept open; its current velocity is 1.6 meters per second. The DELAWARE River flows in a V-shaped channel with relatively steep clay banks. The average width of the river at VALLEY FALLS (TP8858) is 40 meters and the depth is 0.65 meter. PERRY LAKE dam was destroyed several years ago and the lake is no longer a major water obstacle. The DELAWARE River continues south through the now empty lake basin until it joins the KANSAS River west of LAWRENCE.

(2) Vegetation. The vegetation in the area includes row crops, grazing land, orchards, and wooded areas. The principal crops are wheat and corn. The fields are bare after harvesting and their surfaces broken. Deciduous trees grow along the river and creekbeds and on the slopes of the ridges. The tops of the ridgelines are generally clear of heavy vegetation. Most of the roads in the area are bordered by treelines. The wide, open fields in the area are separated in many instances by hedges of osage orange trees.

(3) Surface materials. Generally, the beds and banks of the streams are composed of fine-textured clay-type soil. The ridges are composed of medium-textured limestone-type soil. The cultivated areas are characterized by loose topsoil. Along the ridges, the ground water level is more than 0.60 meter below the surface, and the ground dries quickly even after heavy rains.

(Classification)

Drying of the soil is aided by the frequent moderate-to-high winds that also deposit soil dust on the surface throughout the area.

(4) Manmade features. The north-south roads in the area include Highway 73 from ATCHISON through LEAVENWORTH and then south to Highway 24-40; Highway 159 from vicinity EFFINGHAM south through NORTONVILLE, joining Highway 59 from ATCHISON, southwest through NORTONVILLE and OSKALOOSA to Highway 24 near the KANSAS River; Highway 75 leading south out of SABETHA through HOLTON to TOPEKA; and Highway 63 from PAWNEE CITY through SENECA to ST MARY'S, where it joins Highway 24. There are five primary east-west roads in the area: Highway 4-116 from ATCHISON southwest to STRANGER Creek and then west across the DELAWARE River to HOLTON, where it joins Route 16 and moves west out of the corps sector; Highway 7-192-4-16 from LEAVENWORTH through EASTON and VALLEY FALLS to HOLTON where they join 116. Highway 92 from LEAVENWORTH to OSKALOOSA across the DELAWARE River, where it joins Route 4 and turns south to TOPEKA. Highway 24-40 from KANSAS CITY, KANSAS, through TONGANOXIE, LAWRENCE, along the KANSAS River to TOPEKA, and west to MANHATTAN; and the KANSAS Turnpike, which extends from KANSAS CITY, KANSAS, to LAWRENCE, TOPEKA, and southwest to EMPORIA. All these roads are two-way, hard-surfaced construction. In addition, loose-surfaced secondary roads and some paved state and county roads cross the area generally from north to south and east to west. Bridges on main highways are usually two-way class 60. Bridges on the secondary and farm roads are usually one-way and seldom exceed class 15. One railroad runs north and south from ATCHISON along the MISSOURI River to LEAVENWORTH. It then branches southeast along the MISSOURI River to KANSAS CITY, KANSAS, south to BONNER SPRINGS, southwest to LAWRENCE, and west through TOPEKA to MANHATTAN. From ATCHISON another system curves southwest to vicinity STRANGER Creek where one branch turns west to the DELAWARE River and northwest along the international boundary, and the other continues southwest to VALLEY FALLS and TOPEKA. The Chicago, Rock Island, and Pacific Railroad runs southeast out of PAWNEE CITY to SABETHA and HORTON where it turns southwest to HOLTON leading directly to TOPEKA and further west-southwest to HUTCHINSON. The Union Pacific Railroad runs southeast out of MARYSVILLE to FRANKFORT and TOPEKA, then east to LAWRENCE and KANSAS CITY. The Atchison, Topeka, and Santa Fe Railroad, depicted on current maps as running northwest out of LEAVENWORTH, is no longer in existence.

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3. MILITARY ASPECTS OF THE AREA

a. Tactical Aspects.

(1) Concealment and cover.

(a) Relief. Fair concealment and some cover from direct-fire weapons are provided by the ridges and folds in the ground. In general, creek and stream valleys provide excellent cover throughout the area. Though the principal ridges run northwest to southeast, the Highway 92 ridge-PILOT KNOB complex affords defilade in the north-south direction.

(b) Vegetation. The tops of the principal ridges are generally bare and will provide only limited concealment. On the other hand, the slopes of many ridges are heavily wooded and provide excellent concealment. Typical

(Classification)

(ANAL of AO-1st (US) Corps)

examples of these wooded areas are the western slopes of RIDGE Road Ridge (Highway 17), the northern slopes of Highway 92 ridge, and slopes of the many streams. The vegetation will tend to hold fog, smoke, and chemicals in the area. The natural concealment available in the valleys and along the ridges can be enhanced by the use of smoke.

(2) Observation and fire (to be determined by the student).

* * * * * * *

(b) Relief. Because there are few major terrain features in the area, long-range observation is generally limited. The areas east and west of STRANGER Creek, especially along the bluffs overlooking the MISSOURI River, afford excellent observation over adjacent lowlands. In the LEAVENWORTH area, Highway 92 ridge and PILOT KNOB provide good observation.

(c) Vegetation. Wooded areas, tree-lined roads, and a hedgelike tree line bordering the fields restrict fields of fire and observation throughout the area. The heavily wooded areas on the western slopes of RIDGE Road Ridge and the eastern slopes of the high ground west of STRANGER Creek restrict observation into the STRANGER Creek valley. Effective observation is available from points located along the lower parts of these slopes. Observation from Highway 92 ridge is also restricted to a degree by some areas partially defiladed by hedges and tree lines. The vegetation in the valleys and ravines will tend to hold fog and smoke for increased periods of time thus reducing observation into these areas.

(d) Surface materials. The loose, dry soil on the ridges will produce large dust clouds that will persist for periods up to 1 hour following movement of large numbers of vehicles.

(e) Manmade features. Some of the taller buildings in built-up areas provide excellent observation into surrounding areas. Other structures, such as water towers and the grain elevators throughout the area, afford excellent observation.

(3) Obstacles.

(a) Relief. The rivers and streams in the area constitute the only obstacles. Of major concern are the MISSOURI and KANSAS Rivers and of lesser importance are STRANGER Creek, SALT Creek, DELAWARE River, SOLDIER Creek, VERMILLION Creek, and CROSS Creek. The highway and railroad bridges over these rivers are important to corps operations in the area. Highway bridges are class 60 on most primary roads and are class 10 to 15 on secondary roads. Railroad bridges will take any division load. Highway and railroad bridges span the MISSOURI River at ATCHISON and ST JOSEPH. A highway bridge and a railroad bridge span this river at LEAVENWORTH. Should these bridges be destroyed, a major engineer effort will be needed to provide adequate bridges. The KANSAS River has two highway bridges at LAWRENCE, one highway bridge at EUDORA, one highway bridge at DE SOTO, two highway and two railroad bridges at TOPEKA, one railroad and one highway bridge at BONNER SPRINGS, a highway bridge at TURNER, and eight highway and two railroad bridges in the vicinity of KANSAS CITY, KANSAS. STRANGER Creek is crossed by numerous highway bridges.

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(ANAL of AO-1st (US) Corps)

(b) Vegetation. The wooded areas will impede cross-country vehicular movement.

(4) Key terrain features.

(a) Hill 1250 (QU5252).
(b) Hill 1088 (TP5643).
(c) Hill 1085 (TP6237).
(d) High ground vicinity TP7243.
(e) Hill 1149 (UP1441).
(f) Hill 1162 (TP9841).
(g) Bridges over the KANSAS River from vicinity of BONNER SPRINGS (UP3724) to vicinity of ST MARYS (QU5442).

(5) Avenues of Approach.

(a) Available to PAKLAND forces to the KANSAS River.

1. Avenue 1: ATCHISON (UP1882), along Highway 73, LEAVENWORTH (UP3554), along Highway 7, to BONNER SPRINGS (UP3724).

2. Avenue 2: HURON (TP9890), NORTONVILLE (TP9965), OSKALOOSA (UP0042) to crossing sites adjacent to LAWRENCE (UP0615).

3. Avenue 3: Highway 75 vicinity of the EURLANDIA border (TP6593), HOLTON (TP6572), along Highway 75, to TOPEKA (TP6825).

4. Avenue 4: CORNING (QU5593), ST CLERE (QU5462), to ST MARYS (QU5442).

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4. EFFECTS OF CHARACTERISTICS OF THE AREA (to be determined by the student)

a. Effect on Enemy Courses of Action.

b. Effect on Own Courses of Action.

5. GENERAL WEATHER SUMMARY (1 September--15 October)

September through mid-October is a generally fair and mild period. Moderate temperatures occur as the warm and humid summer airmass begins to subside. Extended periods (10--14 days) of dry and fair weather will occur, with temperatures ranging from a high of 75 to 80°. The majority of rainfall occurs as brief showers and thunderstorms; however, infrequent stationary frontal systems may influence the area toward the end of the period, bringing prolonged rainfall (48--72 hours). There is less than a 5-percent probability of snow during the period.

6. SPECIFIC WEATHER PARAMETERS

a. Temperature (°F):

	Mean Daily Max Sep/Oct	Mean Daily Min Sep/Oct	Extreme Min Sep/Oct	Extreme Max Sep/Oct
FORT LEAVENWORTH	80/72	55/45	28/19	110/98
TOPEKA	80/70	58/47	38/24	104/96
MANHATTAN	81/72	57/46	31/20	112/100

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(ANAL of AO-1st (US) Corps)

b. Humidity (Sep/Oct) (Percentage):

	0400 Sep/Oct	1300 Sep/Oct
FORT LEAVENWORTH	89/84	53/49
TOPEKA	79/76	50/48
MANHATTAN	81/80	50/47

c. Wind (Sep/Oct) (Knots):

	Mean Speed Sep/Oct	Peak Gust Sep/Oct	Prevailing Direction Sep/Oct
FORT LEAVENWORTH	6/6	46/41	S/S
TOPEKA	8/8	42/47	S/S
MANHATTAN	8/8	54/55	S/S

d. Precipitation (in):

	Mean Sep/Oct	24-hr Max Sep/Oct	Mean Snowfall Sep/Oct	Max Snowfall Sep/Oct
FORT LEAVENWORTH	3.1/2.6	4.3/3.4	0/.05	0/.05
TOPEKA	2.8/2.3	2.8/4.8	.05/.05	.05/.05
MANHATTAN	3.5/2.6	3.7/3.5	0/.05	0/.05

e. Ceiling and Visibility (Sep/Oct) (Percentage of time):

	FORT LEAVENWORTH Sep/Oct	TOPEKA Sep/Oct	MANHATTAN Sep/Oct
Less than 3,000 ft and/or 3 mi	15/12	11/12	12/11
Less than 1,500 ft and/or 3 mi	10/8	7/8	7/7
Less than 1,000 ft and/or 2 mi	6/5	5/6	4/4
Less than 200 ft and/or ½ mi	1/1	.5/1	1/.5

7. SOLAR AND MOON DATA

a. Solar Data, Fort Leavenworth (Valid for 20th Century ± 1 min)

(Local Standard Time):

	BMNT	BMCT	SR	SS	EECT	EENT
1 Sep	0447	0520	0548	1851	1918	1951
2 Sep	0448	0521	0539	1849	1917	1949
3 Sep	0449	0522	0550	1848	1915	1948
4 Sep	0451	0523	0550	1846	1914	1946
5 Sep	0452	0524	0551	1845	1912	1944
6 Sep	0453	0525	0552	1843	1910	1943
7 Sep	0454	0526	0553	1842	1909	1941
8 Sep	0455	0527	0554	1840	1907	1939
9 Sep	0456	0528	0555	1838	1905	1937

(Classification)

(Classification)

(ANAL of AO-1st (US) Corps)

	BMNT	BMCT	SR	SS	EECT	EENT
10 Sep	0457	0529	0556	1837	1904	1936
11 Sep	0458	0530	0557	1835	1902	1934
12 Sep	0459	0531	0558	1834	1900	1932
13 Sep	0500	0532	0559	1832	1859	1931
14 Sep	0501	0533	0600	1830	1857	1929
15 Sep	0502	0534	0600	1829	1856	1927
16 Sep	0503	0534	0601	1827	1854	1925
17 Sep	0504	0535	0602	1825	1852	1924
18 Sep	0505	0536	0603	1824	1851	1922
19 Sep	0506	0537	0604	1822	1849	1920
20 Sep	0507	0538	0605	1821	1847	1919
21 Sep	0508	0539	0606	1819	1846	1917
22 Sep	0509	0540	0607	1817	1844	1915
23 Sep	0510	0541	0608	1816	1842	1914
24 Sep	0511	0542	0609	1814	1841	1912
25 Sep	0512	0543	0610	1812	1839	1910
26 Sep	0513	0544	0611	1811	1837	1909
27 Sep	0514	0545	0612	1809	1836	1907
28 Sep	0515	0546	0613	1808	1834	1905
29 Sep	0516	0547	0613	1806	1833	1904
30 Sep	0517	0548	0614	1894	1831	1902
1 Oct	0517	0549	0615	1803	1829	1900
2 Oct	0518	0550	0616	1801	1828	1859
3 Oct	0519	0551	0617	1800	1826	1857
4 Oct	0520	0551	0618	1758	1825	1856
5 Oct	0521	0552	0619	1756	1823	1854
6 Oct	0522	0553	0620	1755	1822	1853
7 Oct	0523	0554	0621	1753	1820	1851
8 Oct	0524	0555	0622	1752	1819	1850
9 Oct	0525	0556	0623	1750	1817	1848
10 Oct	0526	0557	0624	1749	1816	1847
11 Oct	0527	0558	0625	1747	1814	1845
12 Oct	0528	0559	0626	1746	1813	1844
13 Oct	0529	0600	0627	1744	1811	1842
14 Oct	0530	0601	0628	1743	1810	1841
15 Oct	0531	0602	0629	1741	1808	1839

b. Moon Data (1977) Fort Leavenworth (Local Standard Time):

(Classification)

81.7-2231

(Classification)

(ANAL of AO-1st (US) Corps)

	Moon rise	Moon set	Fraction of moon illuminated	Phase*
September				
1	2058	0941	.89	
2	2133	1039	.82	
3	2211	1135	.74	
4	2251	1229	.65	
5	2336	1320	.56	Last quarter
6	----	1409	.46	
7	0024	1455	.37	
8	0115	1537	.28	
9	0210	1617	.20	
10	0308	1654	.12	
11	0409	1729	.07	
12	0511	1804	.02	
13	0615	1839	.00	New moon
14	0720	1915	.00	
15	0827	1952	.03	
16	0934	2033	.08	
17	1041	2119	.16	
18	1147	2209	.25	
19	1249	2305	.36	
20	1346	----	.47	First quarter
21	1437	0005	.58	
22	1524	0108	.69	
23	1605	0213	.79	
24	1641	0318	.87	
25	1716	0422	.94	
26	1750	0525	.98	
27	1823	0627	1.00	Full moon
28	1856	0728	1.00	
29	1931	0826	.97	
30	2008	0923	.93	
October				
1	2047	1019	.87	
2	2130	1112	.80	
3	2216	1202	.72	
4	2306	1248	.63	
5	2358	1331	.54	Last quarter
6	----	1412	.44	

*New moon: Moon's face not illuminated
First quarter: One-half of moon's face illuminated
Full moon: Moon's face fully illuminated
Last quarter: One-half of moon's face illuminated

(Classification)

(Classification)

(ANAL of AO-1st (US) Corps)

	Moon rise	Moon set	Fraction of moon illuminated	Phase*
October continued				
7	0054	1449.	.35	
8	0153	1525	.26	
9	0254	1600	.17	
10	0356	1635	.10	
11	0501	1710	.04	
12	0609	1748	.01	New moon
13	0717	1828	.00	
14	0827	1913	.02	
15	0935	2003	.06	

8. WEATHER FACTORS OF OPERATIONAL SIGNIFICANCE

a. Severe Storms: The transition from the warm, moist summertime airmass to the cool, dry, fall and winter airmasses has the potential for occasional severe thunderstorms. Normally the occurrence of these storms is toward the end of the period when the contrast between airmasses becomes more acute. Operational planning should consider the influence of severe weather. Timing of movements, distribution of resources, and protection of personnel and equipment are important considerations.

b. Trafficability: The gradual decrease in rainfall during the late summer and early fall results in generally good trafficability throughout the region. Brief local restrictions to trafficability may occur in areas influenced by heavy showers or thunderstorms.

c. Flying Weather: Flying weather is good to excellent during the period. Occasional low ceilings and visibilities associated with frontal systems and/or local thunderstorms may only briefly limit flying activities.

(Classification)

MESSAGE: 1

GENERAL ENEMY SITUATION

During the past three weeks, PAKLAND has deployed major maneuver and fire support forces into traditional training areas located approximately 30 kilometers north of the border. The announced reason for this move is to conduct annual training exercises. PAKLAND news media has referred to this as exercise HOT WATER.

PAKLAND'S forces currently conducting this exercise have been identified as elements of the 7th and 10th Tk Armies and the 8th Gd Tk Army, west and north of HORTON, respectively.

Even though these three armies have moved to established training areas, the level of training activity has been lower than normally expected. PAKLAND has been moving supplies forward at an abnormally high rate during the last three days and has been stockpiling these supplies for easy access of all PAKLAND forces. Also of significance is the emergence of a new control group headquarters located in the area of the 8th Gd Tk Army.

MESSAGE: 2

ENEMY ACTIVITIES: GROUND

(1) Activity level has been less than normally experienced during enemy training exercises, with the exception of the 8th Gd Tk Army. The 21st Tk Div HQ is currently communicating from the vicinity of TROY, which is approximately 100 kilometers east of its last known location in the 7th Tk Army area. This information is derived from COMINT sources only.

(2) Heavy road and rail traffic has been observed going into the 8th Gd Tk Army area.

(3) SIGINT indicates that two brigades of army group artillery have moved into the 8th GD Tk Army area. Air reconnaissance has not been able to locate their positions.

MESSAGE: 3

ENEMY ACTIVITIES: AIR

Enemy air activity remains normal.

MESSAGE: 4

ENEMY ACTIVITIES: OTHER

Press releases have reported that General Damin, Commander, Pakland Central Front, will visit the 8th Gd Tk Army on September 28th to observe their training exercises. Communications between a mobile facility in the 8th Gd Tk Army area and suspected group headquarters tend to confirm this report.

MESSAGE: 5

MISCELLANEOUS

a. The 7th Tk Army is commanded by General Konef. He is known to be a studious, cautious individual, who believes in detailed planning and fights his battles "by the book."

b. The commander of the 8th Gd Tk Army is General Malenofski, an aggressive commander, willing to take chances. He very seldom fights in accordance with accepted enemy doctrine.

MESSAGE: 6

GENERAL ENEMY SITUATION

Enemy reconnaissance forces have moved out of the training areas and are now actively conducting reconnaissance operations from HORTON west to CENTRALIA. Communication level: Until approximately 0200 hours, there was an increase in reconnaissance-type traffic along the entire southern PAKLAND border, with most of the concentration in the eastern quarter of the corps zone. Level of activity within the division training areas has dropped below that normally encountered during training exercises.

MESSAGE: 7

ENEMY ACTIVITIES: GROUND

Activity level continues to be less than normally experienced during enemy training exercises, with the exception of the 8th Gd Tk Army. Commencing 16 September there appeared to have been a buildup of forces in the eastern zone of the 8th Gd Tk Army. Headquarters, 10th Tk Div, and 23d Gd Tk Div have relocated eastward and are presently held to be 10 kilometers north of FALLS CITY and HIAWATHA, respectively.

MESSAGE: 8

ENEMY ACTIVITIES: GROUND

Heavy road and rail traffic continues to be observed going into the 8th Gd Tk Army area.

MESSAGE: 9

ENEMY ACTIVITIES: GROUND

It appears as if front, second-echelon artillery units have moved forward.

MESSAGE: 10

ELECTRONIC WARFARE

(1) Strict SIGSEC measures have been imposed on the 7th Tk Army artillery units.

(2) At 190200, all enemy units went under radio silence.

APPENDIX B
COMPUTER PRINTOUTS SHOWING HOW ONE OF THE EXPERIENCED ANALYSTS USED THE INTERACTIVE BAYESIAN INFERENCE AID

INTRODUCTION

THIS PROGRAM WILL BE PARTICULARLY HELPFUL TO YOU WHEN:

1. YOU ARE USING IPB PROCEDURES; YOU ARE CREATING YOUR EVENT MATRIX; YOU HAVE COMPLETED YOUR TERRAIN, OB, AND WEATHER ANALYSES.

2. YOU HAVE SOME INTELLIGENCE THAT SUPPORTS MORE THAN ONE COURSE OF ACTION.

THE PURPOSE OF THIS PROGRAM IS TO HELP YOU ANALYZE THE RELATIVE LIKELIHOODS OF ALTERNATIVE ENEMY COURSES OF ACTION (COAS).

PRESS EXECUTE TO CONTINUE.

PRESS EXECUTE TO CONTINUE.
THE PROGRAM WORKS BY BREAKING YOUR ANALYSIS DOWN INTO THREE PHASES:

(1) DEFINING THE ALTERNATIVE COAS. HOW MANY ARE THERE? WHAT ARE THEIR NAMES?

(2) ASSESSING THE LIKELIHOOD OF EACH COA TAKING INTO ACCOUNT WHATEVER INTELLIGENCE INFORMATION YOU HAVE ON HAND, PRIOR TO RECEIVING ANY NEW INTELLIGENCE INFORMATION. THIS PRIOR INFORMATION DEALS WITH TERRAIN, OB, WEATHER, AND SO FORTH.

(3) ASSESSING HOW EACH PIECE OF NEW INTELLIGENCE YOU RECEIVE IMPACTS THE ORIGINAL LIKELIHOODS YOU ESTIMATED IN STEP 2.

PRESS EXECUTE TO CONTINUE.

MAIN OPTIONS

1) PERFORM AN ANALYSIS
2) OUTPUT ANALYSIS RESULTS
3) RETRIEVE OR STORE ANALYSIS RESULTS

TYPE THE NUMBER OF THE DESIRED OPTION: 1

ANALYSIS OPTIONS

1) DEFINE THE ALTERNATIVE COAS
2) ASSESS INITIAL COA LIKELIHOODS
3) ASSESS IMPACT OF NEW INTELLIGENCE ON COA LIKELIHOODS

TYPE THE NUMBER OF THE DESIRED OPTION: 1

PHASE I: DEFINE THE ALTERNATIVE COAS

HOW MANY COURSES OF ACTION (COAS) DO YOU WANT TO CONSIDER?

HOW MANY COURSES OF ACTION (COAS) DO YOU WANT TO CONSIDER? 4

FOR EACH COURSE OF ACTION (COA), TYPE UP TO THIRTY LETTERS FOR A LONG NAME, AND UP TO THREE LETTERS FOR A SHORT NAME.

COA 1 (LONG): 52 MECH R SECTOR
COA 1 (SHORT): 1
COA 2 (LONG): 52 MECH C SECTOR
COA 2 (SHORT): 2
COA 3 (LONG): 23 AR R SECTOR
COA 3 (SHORT): 3
COA 4 (LONG): 23 AR L SECTOR
COA 4 (SHORT): 4

ANALYSIS OPTIONS

1) DEFINE THE ALTERNATIVE COAS
2) ASSESS INITIAL COA LIKELIHOODS
3) ASSESS IMPACT OF NEW INTELLIGENCE ON COA LIKELIHOODS

TYPE THE NUMBER OF THE DESIRED OPTION: 2

PHASE II: ASSESS INITIAL COA LIKELIHOODS

THE POSSIBLE COAS ARE:

1) 52 MECH R SECTOR
2) 52 MECH C SECTOR
3) 23 AR R SECTOR
4) 23 AR L SECTOR

GIVEN ALL PRIOR INTELLIGENCE DATA (E.G., TERRAIN ANALYSIS, OB, WEATHER), RANK ORDER THE COAS FROM MOST TO LEAST LIKELY.
TYPE EACH NUMBER FOLLOWED BY A SPACE: 2 3 1 4
HOW MANY TIMES AS LIKELY IS 2 AS COMPARED WITH 3 ? 1
HOW MANY TIMES AS LIKELY IS 2 AS COMPARED WITH 1 ? 2
HOW MANY TIMES AS LIKELY IS 2 AS COMPARED WITH 4 ? 3

ASSESSED PRIOR ODDS:

2 VS 3	2 VS 1	2 VS 4
1.00	2.00	3.00

BASED ON YOUR ASSESSMENTS OF THE PRIOR ODDS, THE CALCULATED PRIOR PROBABILITIES OF THE COAS ARE:

1	2	3	4
.18	.35	.35	.12

GIVEN ALL PRIOR INFORMATION, DO THESE PRIOR PROBABILITIES ACCURATELY REFLECT YOUR CURRENT PERCEPTION OF THE LIKELIHOODS OF YOUR COAS? Y

YOU HAVE NOW COMPLETED PHASE II, ASSESSMENT OF INITIAL COA LIKELIHOODS. YOU SHOULD NOW EVALUATE THE IMPACT OF WHATEVER NEW INTELLIGENCE INFORMATION YOU RECEIVE. THIS INFORMATION WILL TAKE THE FORM OF REPORTS OF OBSERVED ENEMY ACTIVITIES. TO MAKE THESE ASSESSMENTS, SELECT OPTION 3 FROM THE OPTIONS WHICH WILL BE DISPLAYED NEXT.

PRESS EXECUTE TO CONTINUE.

ANALYSIS OPTIONS

1) DEFINE THE ALTERNATIVE COAS
2) ASSESS INITIAL COA LIKELIHOODS
3) ASSESS IMPACT OF NEW INTELLIGENCE ON COA LIKELIHOODS

TYPE THE NUMBER OF THE DESIRED OPTION: 3

PHASE III: ASSESSING THE IMPACT OF NEW INTELLIGENCE

PRESS EXECUTE TO CONTINUE.

0 REPORT(S) OF NEW INTELLIGENCE HAVE BEEN ENTERED SINCE YOUR ASSESSMENT OF THE PRIOR PROBABILITIY OF EACH COA.

PRESS EXECUTE TO CONTINUE.
THE PRIOR PROBABILITIES OF THE COAS ARE:

1	2	3	4
.18	.35	.35	.12

THE CORRESPONDING PPIOR ODDS ARE:

2 VS 3	2 VS 1	2 VS 4
1.00	2.00	3.00

TYPE A LONG (30 LETTER) AND A SHORT (3 LETTER) NAME FOR THE OBSERVED ENEMY ACTIVITY.

LONG NAME: GENERAL EN SIT
SHORT NAME: #1

IN THE NEXT STEP YOU WILL BE ESTIMATING THE LIKELIHOOD THAT YOU WOULD OBSERVE #1 IF IN FACT THE ENEMY WERE ACTUALLY PURSUING A GIVEN COA.

PRESS EXECUTE TO CONTINUE.

```
THE POSSIBLE COAS ARE:

 1) 52 MECH R SECTOR
 2) 52 MECH C SECTOR
 3) 23 AR R SECTOR
 4) 23 AR L SECTOR

GIVEN ALL KNOWLEDGE OF THE SITUATION AT HAND,
UNDER WHICH COA WOULD YOU BE
MOST LIKELY TO SEE #1 : 2
SECOND MOST LIKELY: 3
THIRD MOST LIKELY: 1
FOURTH MOST LIKELY: 4

GIVEN ALL OF YOUR KNOWLEDGE OF THE SITUATION, HOW MANY TIMES
AS LIKELY IS #1  IF THE ENEMY HAD CHOSEN TO PURSUE

2    RATHER THAN 3  ? 1
2    RATHER THAN 1  ? 2
2    RATHER THAN 4  ?  3
GIVEN THE LIKELIHOOD RATIOS THAT YOU HAVE PROVIDED, THE
POSTERIOR PROBABILITIES OF THE COAS ARE:

  1     2     3     4
 .11   .42   .42   .05

AND THE CORRESPONDING POSTERIOR ODDS ARE:

            2       2       2
           VS      VS      VS
            3       1       4
          1.00    4.00    9.00

DO THESE POSTERIOR PROBABILITIES AND ODDS ACCURATELY REFLECT
YOUR FEELINGS CONCERNING THE LIKELIHOODS OF THE COAS? N
```

THE PRIOR PROBABILITIES FOR THE COAS BEFORE THE REPORT OF #1 WERE:

1	2	3	4
.18	.35	.35	.12

INCLUDING INFORMATION CONCERNING THE CURRENT DATUM, THE PROBABILITIES ARE:

1	2	3	4
.11	.42	.42	.05

PLEASE SPECIFY A SET OF POSTERIOR PROBABILITIES THAT ACCURATELY REFLECTS HOW LIKELY YOU CONSIDER EACH COA TO BE, GIVEN ALL AVAILABLE INFORMATION.
TYPE YOUR DIRECT ASSESSMENTS OF THE POSTERIOR PROBABILITIES FOR ALL COAS: .18 .35 .35 .12

THE LIKELIHOOD RATIOS IN THE FOLLOWING TABLE ARE CALCULATED FROM YOUR DIRECTLY ASSESSED POSTERIOR PROBABILITIES. THEY SHOW HOW MANY TIMES AS LIKELY THE OBSERVED ENEMY ACTIVITY (#1) WOULD BE, GIVEN THAT THE ENEMY HAD CHOSEN TO PURSUE 3 RATHER THAN EACH OF THE OTHER COAS.

PRESS EXECUTE TO CONTINUE.

CALCULATED LIKELIHOOD RATIOS:

2 VS 3	2 VS 1	2 VS 4
1.00	.97	.97

ASSESSED LIKELIHOOD RATIOS:

2 VS 3	2 VS 1	2 VS 4
1.00	2.00	3.00

PRESS EXECUTE TO CONTINUE.

THE LIKELIHOOD RATIOS CALCULATED FROM YOUR DIRECTLY ASSESSED POSTERIOR PROBABILITIES ARE DIFFERENT THAN YOUR DIRECTLY ASSESSED LIKELIHOOD RATIOS FOR #1 . YOU MAY WISH TO REVISE YOUR DIRECTLY ASSESSED POSTERIOR PROBABILITIES OR YOUR DIRECTLY ASSESSED LIKELIHOOD RATIOS OR LEAVE THEM AS THEY ARE. IT IS NOT NECESSARY THAT YOU REVISE EITHER IF THEY BOTH ACCURATELY REFLECT YOUR TRUE FEELINGS.

PRESS EXECUTE TO CONTINUE.

```
 1) REVISE POSTERIOR PROBABILITIES FOR THE COAS
 2) REVISE LIKELIHOOD RATIOS FOR THE OBSERVED ENEMY ACTIVITY #1
 3) REVISE NEITHER

TYPE THE NUMBER OF THE DESIRED OPTION:  2



SUMMARY TABLE FOR LIKELIHOOD RATIOS:

            2        2        2
           VS       VS       VS
            3        1        4
ORIGINAL   1.00     2.00     3.00
CALCULTD   1.00      .97      .97

YOUR CURRENT RANK FOR THE LIKELIHOOD OF #1  GIVEN EACH COA IS: 2 3 1 4

HAS YOUR RANK CHANGED? N
```

SUMMARY TABLE FOR LIKELIHOOD RATIOS:

	2 VS 3	2 VS 1	2 VS 4
ORIGINAL	3.00	2.00	1.00
CALCULTD	1.00	.97	1.00

GIVEN ALL THE DATA YOU HAVE HAD UP TO THIS POINT,
HOW MANY TIMES AS LIKELY IS THE CURRENT DATUM IF
THE ENEMY HAD CHOSEN TO PURSUE

2 RATHER THAN 3 ? 1
2 RATHER THAN 1 ? 1
2 RATHER THAN 4 ? 1

SUMMARY TABLE FOR PRIOR AND POSTERIOR PROBABILITIES:

	1	2	3	4
PRIOR	.10	.35	.35	.12
CALCULTD	.10	.35	.35	.12
ASSESSED	.10	.35	.35	.12

YOUR ASSESSED POSTERIOR PROBABILITIES ARE NEARLY EQUAL TO THE
CALCULATED POSTERIOR PROBABILITIES.

DO YOU WISH TO CONTINUE THE ANALYSIS OF #1 ? N

DO YOU WISH TO CONTINUE THE ANALYSIS BASED ON
ANOTHER, NEWLY OBSERVED ENEMY ACTIVITY? Y

1 REPORT(S) OF NEW INTELLIGENCE HAVE BEEN ENTERED SINCE YOUR ASSESSMENT OF THE PRIOR PROBABILITIY OF EACH COA.

PRESS EXECUTE TO CONTINUE.
THE PRIOR PROBABILITIES OF THE COAS ARE:

1	2	3	4
.10	.35	.35	.12

THE CORRESPONDING PRIOR ODDS ARE:

2 VS 3	2 VS 1	2 VS 4
1.00	1.94	2.92

TYPE A LONG (30 LETTER) AND A SHORT (3 LETTER) NAME FOR THE OBSERVED ENEMY ACTIVITY.

LONG NAME: GROUND ACTIVITY
SHORT NAME: #2

IN THE NEXT STEP YOU WILL BE ESTIMATING THE LIKELIHOOD THAT YOU WOULD OBSERVE #2 IF IN FACT THE ENEMY WERE ACTUALLY PURSUING A GIVEN COA.

PRESS EXECUTE TO CONTINUE.

```
THE POSSIBLE COAS ARE:

 1) 52 MECH R SECTOR
 2) 52 MECH C SECTOR
 3) 23 AR P SECTOR
 4) 23 AR L SECTOR

GIVEN ALL KNOWLEDGE OF THE SITUATION AT HAND,
UNDER WHICH COA WOULD YOU BE
MOST LIKELY TO SEE #2 : 2
SECOND MOST LIKELY: 3
THIRD MOST LIKELY: 1
FOURTH MOST LIKELY: 4

GIVEN ALL OF YOUR KNOWLEDGE OF THE SITUATION, HOW MANY TIMES
AS LIKELY IS #2  IF THE ENEMY HAD CHOSEN TO PURSUE

2   RATHER THAN 3  ? 1
2   RATHER THAN 1  ? 1
2   RATHER THAN 4  ? 1
GIVEN THE LIKELIHOOD RATIOS THAT YOU HAVE PROVIDED, THE
POSTERIOR PROBABILITIES OF THE COAS ARE:

  1     2     3     4
 .18   .35   .35   .12

AND THE CORRESPONDING POSTERIOR ODDS ARE:

          2     2     2
         VS    VS    VS
          3     1     4
        1.00  1.94  2.92

DO THESE POSTERIOR PROBABILITIES AND ODDS ACCURATELY REFLECT
YOUR FEELINGS CONCERNING THE LIKELIHOODS OF THE COAS? Y
DO YOU WISH TO CONTINUE THE ANALYSIS BASED ON
ANOTHER, NEWLY OBSERVED ENEMY ACTIVITY? Y
```

APPENDIX C
DATA FORMS USED TO ESTIMATE THE PRIOR ODDS, LIKELIHOOD RATIOS, AND POSTERIOR ODDS IN THE UNAIDED CONDITION

Participant Number _____ Date _____

ANSWER SHEET FOR PRIOR ODDS

1. Rank order the AOAs from most to least likely, based upon the set of background intelligence data.

   Most Likely AOA: _____
   Second Most Likely _____
   Third Most Likely _____
   Least Likely AOA _____

2. Indicate how many times as likely the most likely AOA is versus each of the other AOAs:

   (a) Most versus second most likely AOA _____
   (b) Most versus third most likely AOA _____
   (c) Most versus least likely AOA _____

Participant Number _____ Date _____

Message _____

ANSWER SHEET FOR LIKELIHOOD RATIOS

1. Rank order the AOAs in terms of the message.

   (a) AOA for which you would be most likely to receive message: _____
   (b) Second most likely AOA: _____
   (c) Third most likely AOA: _____
   (d) Least likely AOA: _____

2. Indicate how many times as likely you would be to receive the message, given the most likely AOA versus each of the other AOAs.

   Note: These are the likelihood ratios (LR).

   (a) Most likely versus second most likely AOA: _____
   (b) Most likely versus third most likely AOA: _____
   (c) Most likely versus least likely AOA _____

Participant Number _____ Date _____

Message _____

ANSWER SHEET FOR POSTERIOR ODDS

1. Rank order the AOAs from most to least likely, keeping in mind the prior odds (posterior odds resulting from the last message) and the likelihood ratios for the message.

   Most likely AOA: _____
   Second most likely: _____
   Third most likely: _____
   Least likely AOA: _____

2. Indicate how many times as likely the most likely AOA is as compared with each of the other AOAs:

   (a) Most versus second most likely AOA _____
   (b) Most versus third most likely AOA _____
   (c) Most versus least likely AOA _____

APPENDIX D
GENERAL QUESTIONNAIRE AND SUMMARY REPORT FORM USED IN THE RESEARCH STUDY

Participant Number _____ Message No. _____

GENERAL QUESTIONS

1. As the Division G2, would you request an immediate briefing with the Division Commander after this message?

   Yes or No (Circle One)

   Explain briefly: _____

2. As the Division G2, would you request additional information from Corps after this message?

   Yes or No (Circle one)

   Explain briefly _____

3. At this point, would you conclude that the enemy has selected a primary avenue of approach?

   Yes or No (Circle one)
   If Yes, which avenue of approach? _____
   Explain briefly _____

Participant Number _____ Date _____

SUMMARY REPORT

Write your intelligence estimate at this time. That is, rank order the AOAs from most to least likely and justify your answer. Be sure to include all information the G2 will need in presenting your estimate to the commander.